PHYTOPATHOLOGY

VOLUME II NUMBER 2

APRIL, 1912

INOCULATION EXPERIMENTS WITH FUNGI ASSOCIATED WITH APPLE LEAF SPOT AND CANKER

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A large number of fungi have been reported as occurring on the wood and leaves of the apple in different localities. Part of these have been definitely proved to be parasites but many have never been tested by means of inoculation experiments to determine the extent of their parasitism. In 1908 a study of the fungi associated with apple diseases in Maine orchards was begun and it is proposed to give in this publication the results of inoculations made with fungi isolated from diseased branches and leaves.

APPLE LEAF SPOT

The leaf spot of the apple is a common and widely distributed disease. It has been reported from many of the states in the eastern half of the United States and probably occurs in all of them. It is of frequent occurrence in Maine, especially in orchards which have not received good care in the matters of cultivation, fertilization, pruning and spraying. In this connection attention should be called to the fact that very frequently leaves are injured by the spray materials and spotting results. Certain varieties of apples are more susceptible to spray injury than others and the weather conditions at the time of spraying have a very marked effect on the results. It is a matter of common observation, however, that many orchards which have not been sprayed are affected by a spotting of the leaves which in some cases is quite serious. The spots on unsprayed leaves and those resulting from spray injury are often so similar, especially late in the summer, that one cannot be distinguished from the other. To determine whether leaves in an orchard have been injured by spraying or are suffering from some other cause it is necessary to compare sprayed and unsprayed trees of the same variety which have been treated alike in other respects.

The first indication of leaf spot is the appearance of small purple spots scattered over the affected leaves. These spots increase in size,

are usually somewhat circular in outline, and the center becomes dead and is brown in color. When a large number of spots occur on a leaf they may run together. On the dead spots one frequently finds little black fruiting bodies of fungi. These fungi may occur in some cases on dead spots in apple leaves which have been killed by sprays or by other causes so that the presence of a fungus is not good evidence that the fungus caused the spots.

The leaf spot of apples has been discussed by a large number of writers and the cause has been attributed to a number of different fungi. Each of these fungi was found so constantly associated with the spots in the locality from which the disease was described as to lead to the conclusion that the spotting was caused by that fungus. The fungi most frequently mentioned as causing the disease are *Phyllosticta limitata* Pk., *Coniothyrium pirina* (Sacc.) Sheldon, and *Sphaeropsis malorum* Pk.

Of recent years it has been questioned whether the presence of the fruiting portion of a fungus on a leaf spot was good evidence that the fungus caused the disease. It has been held that it is necessary to isolate the fungus, grow it in pure cultures and by means of inoculations determine whether it can cause the disease.

Among the first to question the parasitism of the fungi found fruiting on leaf spots were Stewart and Eustace[1] who suggested that *Phyllosticta pirina* Sacc. and *Phyllosticta limitata* Pk. which were very common on the dead spots in apple leaves in New York orchards in 1902 were not the causes of the spotting but developed as saprophytes on the spots which had been killed by spray injury or by weather conditions. They suggested that in some cases when bright sunshine follows showers the raindrops on the leaves may act as lenses and so the tissues underneath the drops become heated and are killed.

Stone and Smith[2] attributed a severe outbreak of leaf spot in Massachusetts to frosts at the time when the buds were opening. In some cases the spots did not develop until August but they considered the cold unfavorable spring weather the original cause of the spotting.

In the summers of 1906 and 1907, Scott and Rorer[3] made a study of the disease in Arkansas in which they isolated fungi from leaf spots and carried on inoculation experiments. They found that no one fungus fruited constantly on the spots in that region. *Coniothyrium*

[1] Stewart, F. C. and Eustace, H. F. New York Agr. Exp. Sta. Bul. 220: 225-233. 1902.

[2] Stone, George E., and Smith, Ralph E. Mass. Agr. Exp. Sta. Rep. **15**: 32-34. 1902.

[3] Scott, W. M., and Rorer, J. B. U. S. Dept. Agr., Bur. Pl. Ind. Bul. 121: 47-54. 1908.

pirina, *Sphaeropsis malorum*, 2 species of Pestalozzia and one each of Coryneum, Hendersonia and Alternaria were found. During the summer of 1907 several sets of inoculations were made using spores from cultures of *Sphaeropsis malorum*, *Coniothyrium pirina*, Coryneum, Hendersonia and Alternaria. As a result of these inoculations it was found that *Sphaeropsis malorum* was the only one of these which caused the disease when sprayed upon the healthy leaves of orchard trees.

Sheldon [1] has described a leaf spot from West Virginia which does a great deal of injury causing almost complete defoliation in some cases. An undescribed fungus was found so constantly associated with the spot that it was regarded as the cause. The fungus was described and named *Illosporium malifoliorum* n. sp.

On account of the importance of leaf spot in Maine it was thought desirable to make a study of the disease in order to determine what fungi cause the spotting under Maine conditions. This work seemed all the more necessary because very little had ever been done in studying the fungi which cause diseases of the apple in this state. In the summer of 1908 a study of the causes of leaf spot was begun. Leaves showing the spots were collected from unsprayed orchards from widely separated localities. Examination of the leaves showed that a considerable number of fungi fruited on the dead spots. In some collections one fungus would occur most abundantly while in others another would predominate. Cultures were made by the poured plate method and the following fungi were isolated: *Sphaeropsis malorum*, *Coryneum foliicolum* Fckl., *Coniothyrium pirina* (Sacc.) Sheldon, *Phyllosticta limitata* Pk., *Phoma mali* Schulz & Sacc., *Cladosporium herbarum* (Pers.) Link, *Dematium pullulans* De Bary, one species of Alternaria, one species of Macrosporium, and 3 other fungi which were not determined.

The first work in the isolation of the fungi could not be begun until the second week in July and consequently it was after the middle of July before cultures were secured which were producing spores. As soon as cultures were secured which showed sufficient quantities of spores, attempts were made to infect leaves in the orchard by spraying upon them the spores of *Sphaeropsis malorum*, *Coniothyrium pirina*, *Coryneum foliicolum* and *Phyllosticta limitata* from pure cultures. These fungi were all producing spores in great numbers at that time. The material was crushed in sterile water and was sprayed on the leaves of trees in an orchard at Orono with an atomizer.[2] Sterilized water was

[1] Sheldon, J. L. A leaf spot fungus of the apple. Torreya **8**: 139-141. 1908.

[2] The atomizers used had all the parts which would come in contact with the liquid of glass and metal so that after using with one fungus they could be sterilized by heating before they were used with another.

sprayed on the leaves of other branches of the same trees to serve as checks. On each tree the spores of each fungus were sprayed on the leaves of two branches, then one branch in each case was covered by tying over it a large paper bag as it was thought that this would prevent drying out and would give the germ tubes a better chance to enter the leaves. It was realized that the weather conditions at this time were quite different from what they were a few weeks earlier when there was much more moisture. The work was done after 5 P. M. and the paper bags were not removed until 2 days later at the same hour.

Observations were made from time to time but no spots ever developed on any of these leaves. Another set of inoculations was made on younger trees in the same orchard a few days later. This work also was done in the evening, the same 4 fungi were used, but no spots developed on any of the leaves.

During the winter of 1908-1909 a large number of apple seedlings were grown in the greenhouse. These were transplanted to separate pots when they had a few leaves each. Sets of 6 seedlings in each case were inoculated by spraying upon them the spores of the following fungi: *Sphaeropsis malorum*, *Phyllosticta limitata*, *Coniothyrium pirina*, *Coryneum foliicolum*, *Phoma mali*, an Alternaria, probably *A. fasciculata* and an undertermined fungus which had been isolated from a leaf spot the summer before. In all cases spores which were known to be living were used in making the inoculations. Several sets of the seedling trees were used in the work with Sphaeropsis. Part of the seedlings in each case were placed in a moist chamber after inoculation. In no case was there any indication of development of leaf spot on these seedlings although it seemed that the conditions were as favorable for infection as could be provided under greenhouse conditions unless the leaves of the seedling trees might be very resistant to attack by the fungi.

Baldwin apple trees one year from the bud were secured in the fall of 1908 from a New York nursery. These trees were kept in a cold cellar during the winter and were brought into the greenhouse early in the spring of 1909 and placed in large pots. These trees came into leaf early and gave a good opportunity to test out some of the fungi before trees in the orchard were far enough advanced for this work. Moreover, the rapidly growing shoots of the young trees seemed to offer very favorable material for these inoculations. A moist chamber was arranged by using a large bell jar, as illustrated in Fig. 17 of Bulletin 170 of the Maine Station, and part of the trees used with each fungus were placed in this moist chamber for a few days after inocu-

lation. Part of these trees were also used in testing out certain of the fungi isolated from the leaves as to the extent of their parasitism on apple wood. A somewhat detailed account of the study of two of these has been published,[1] and these will be referred to only in so far as it is necessary to do so for comparison with the results with other species.

During the month of April, 5 trees were inoculated with Sphaeropsis at different times. Each tree was kept in the moist chamber for a few days after inoculation. On one of the trees a small number of spots developed. These started as small purple spots which were similar to developing spots on leaves in the orchard.

One of these trees was inoculated by spraying it with spores of *Phyllosticta limitata* April 16. This tree was kept in a moist chamber for one week and observations were made on it for several weeks after its removal but no spots appeared. Another tree was inoculated with Phyllosticta April 22. This tree was of particular interest inasmuch as part of the leaves showed small dead spots of irregular shape and size at the time of inoculation. It could readily be seen that these spots were not due to the growth of an organism and they had the appearance of being killed by scalding. Possibly the tissues were killed by the heat of the sun shining through the glass when there was water on the leaves. Material of the fungus which contained many pycnidia which were producing great quantities of spores was crushed in sterilized water and this was sprayed on the leaves with an atomizer. The tree was then placed in a moist chamber. Examination of this tree 8 days later showed that a large number of pycnidia had developed on the dead spots. Microscopic examination proved that the fungus fruiting on the dead spots was identical with the one used in making the inoculations. No new spots developed either from the spores which had been sprayed on the leaves or from the spores which had been produced on the dead spots. It would seem that if this fungus were parasitic the spores borne on the dead spots being carried to other leaves in watering would cause the spots.

A tree which was in good leaf, all the leaves of which were healthy, was sprayed with spores of *Coniothyrium pirina* April 20. The tree was kept in a moist chamber for one week. No spots developed on the leaves. Another tree was inoculated May 1. In this case spots in several leaves were first injured by touching them with a hot needle. The spores were then sprayed on and the tree was placed under a bell-jar. One week later the fungus was found fruiting on a part of the spots especially those which had been very moist. On uninjured

[1] Lewis, C. E. Apple diseases caused by *Coryneum foliicolum* and *Phoma mali*. Me. Exp. Sta. Bul. 170. 1909.

leaves the fungus did not gain entrance and no spots developed. The fungus did not spread from the dead spots on which it was growing into the surrounding green tissue to a sufficient extent that any enlargement of the dead spots could be noted.

Other trees were inoculated with *Coryneum foliicolum* in exactly the same manner which has been described for Coniothyrium. This fungus also developed readily on spots which had been killed and produced large black masses of spores but in no case did the fungus attack the uninjured leaves or spread to any extent from the dead spots into the surrounding tissue thus enlarging the spots.

Inoculations were made in the orchard June 2 and 3, 1909, on trees of McIntosh in the manner which has been described. The spores were abundant and were tested to make sure that they would germinate readily. The work was done in the evening.

Spores of Sphaeropsis, Coryneum and Coniothyrium were used on June 2. The next day was sunny and that evening the branches which had been inoculated were sprayed again with material of the same fungi. Material from agar cultures of Coryneum, which were producing a great many spores, was placed on a part of the leaves which had been inoculated with that fungus. Other branches were sprayed with spores of *Phoma mali* and *Phyllosticta limitata*. On June 4 all the branches which had been inoculated were sprayed with sterile water.

Observations were made from time to time and on July 1 it was noted that a number of leaf spots were developing on the leaves which has been inoculated with Sphaeropsis while the leaves inoculated with the other fungi showed no spots. The spots on the leaves inoculated with Sphaeropsis were counted July 10 and it was found that 44 spots were present. On other branches of the same tree the same number of leaves never showed more than 1 to 4 spots as the orchard was very free from leaf spot.

Some of the young purple spots were cut from the inoculated leaves and after thorough washing in sterile water were placed in plates of prune agar July 10. The fungus grew out quickly and after 4 days the mycelium indicated that Sphaeropsis had grown from each of the pieces. The pycnidia of Sphaeropsis developed very early in these plates so that July 16 spores were found which were brown in color. On this date spores from these cultures were sprayed on 4 of the young Baldwin trees in the greenhouse and July 20 these 4 trees were re-inoculated and 2 others inoculated. No spots were produced on these trees. That the spores used were mature enough to germinate readily was proved by sowing some of them in plates of prune agar, where they germinated and formed colonies which showed mature pycnidia at the

end of a week. Spores from these pycnidia were sprayed on leaves of 3 different trees in the orchard July 23 but no spots developed.

The results of these inoculation experiments seem to indicate that Sphaeropsis is able to attack the leaves of orchard trees when they are inoculated early in the season under favorable conditions for growth. No spotting has been produced by any of the other fungi which have been tested although it has been found that they grow readily on dead spots which have been killed by other causes. This agrees with the results obtained by Hartley [1] who carried on inoculation experiments on seedling apple trees with *Coniothyrium pirina* and *Coryneum foliicolum* and found that neither of these fungi attacked the healthy leaves although both grew on injured places in the leaves. From the results reported in this paper the leaves of young seedling trees do not seem to be very susceptible to attack since none of the seedlings which were inoculated with Sphaeropsis spores developed spots, although an attempt was made to make the conditions as favorable for infection as possible because it was recognized that the conditions in the orchard in the early part of the season are more favorable to infection than greenhouse conditions.

The failure to produce spots on leaves inoculated in July in either 1908 or 1909, together with the same results obtained by Lewis [2] in New Hampshire in 1908, leads to the conclusion that the older leaves are not so susceptible to infection as young leaves. Spots which have started to develop earlier in the season increase in size during the summer but few new spots appear. This is of importance in looking for remedies for the disease. If infection takes place in the early part of the season, the early sprayings should control it and, fortunately, the sprayings which are necessary to control apple scab come at the proper time for the leaf spot fungus. Care must be used, however, in selecting and applying the spray, or spray injury may cause more spots on the leaves of certain tender varieties which are very susceptible to spray injury than are found on neighboring unsprayed trees. Spraying with bordeaux mixture cannot be recommended as a remedy for leaf spot without taking into consideration the fact that the leaves of certain varieties are very susceptible to injury by that spray. Hedrick [3] has prepared a list in which apples are classified according to their immunity to bordeaux injury. Where such injury results it is recommended that a thorough trial be made

[1] Hartley, Carl P. Some apple leaf-spot fungi. Science N. S. **28**: 157-159. 1908.

[2] Lewis, Isaac M., N. H. Exp. Sta. Rep. **20**: 365-369. 1908.

[3] Hedrick, U. P., N. Y. Exp. Sta. Bul. 287: 142. 1907.

of some of the other spray materials which are now available rather than that spraying be given up. There is considerable evidence that some of the lime-sulphur compounds will go far toward controlling the fungi which cause diseases of apple foliage with a minimum of leaf injury when properly prepared and applied.

The fungus leaf spot causes a considerable amount of loss in Maine orchards and this loss is not always realized by apple growers. The dead spots in the leaves interfere with their function and in addition to this large numbers of the diseased leaves fall before the time for the fall of healthy leaves and this seriously interferes with the nutrition of the trees.

Since the same fungus, *Sphaeropsis malorum*, which causes the leaf spot also causes the black rot of the fruit and a canker of the bark it becomes very important that the fungus should be controlled. There is no one means by which all the diseases caused by this fungus can be prevented. All 3 of the diseases are almost sure to occur in neglected orchards. The leaves of trees which are well fertilized and are kept in healthy growing condition by cultivation are not so susceptible to attacks by the leaf spot fungus as are the leaves of neglected trees. Care in pruning out and burning all dead wood removes much material which might be a source of infection for the leaves and fruit. Sphaeropsis not only fruits in the old cankers on large branches but the pycnidia are found on small dead branches and on water sprouts, so that in orchards which are not carefully pruned great numbers of the spores are always present. The importance of burning the wood which is cut out cannot be over emphasized as not only Sphaeropsis but other fungi grow readily as saprophytes on dead apple wood so the spores of decay fungi are present when the fruit is mature enough to be attacked by such fungi.

INOCULATION OF APPLE BRANCHES

In connection with the study of apple leaf spot a study was made of the fungi found on twigs and branches. In this work diseased material has been examined from different parts of Maine as it has been sent in by correspondents and also special trips have been made into the apple growing portions of the State for the purpose of collecting such material. Pure cultures have been made from diseased twigs and branches and a part of the fungi have been tested by means of inoculations to determine the extent of their parasitism on wood and fruit.

The fungi most frequently found on dying twigs and branches of the apple in Maine are: *Sphaeropsis malorum*, *Myxosporium corti-*

colum Edgerton, *Coryneum foliicolum*, *Cytospora* sp., *Phoma mali*, and *Coniothyrium pirina*. In addition to these when plate cultures are made other fungi often develop. Among these is *Phyllosticta limitata* which has been isolated a number of times from small living twigs which were covered with a black growth as well as from dead twigs. This fungus has a characteristic appearance in plate cultures and was determined by its similarity to cultures of the fungus from the leaves. Other fungi found in such plate cultures are: *Dematium pullulans*, *Cladosporium herbarum*, *Alternaria* sp. and *Macrosporium* sp., colonies of Fusarium and of Epicoccum are also found but not so frequently as the others. *Glomerella rufomaculans* (Berk.) Sp. & von Sch., has been found a few times in cankers but is not of common occurrence.

The large number of fungi which occur in cankers and on diseased twigs made it seem desirable to determine which of these are capable of causing disease when inoculated into healthy living wood. This work fitted in well with the work on leaf spot and a part of the fungi isolated from the leaves were used in making inoculations on the wood. Part of the results of this study were published in Bulletin 170 of the Maine Station, and the conclusions in regard to the parasitism of certain of the fungi discussed in Bulletin 185 are based largely upon these inoculation experiments.

In the spring of 1909 trees grown in pots in the greenhouse were used for testing a number of the fungi. Those which attacked the wood of these trees were inoculated into branches of trees in the orchard. In the spring of 1910 seedling trees a little more than one year old were used for some inoculations. These seedling trees had grown slowly and proved to be rather resistant to attack even by such well known parasitic fungi as *Sphaeropsis malorum* and *Glomerella rufomaculans*. Inoculations were made with these two fungi in order that the disease caused by any of the others might be compared with them as well as with check incisions in the bark to which no fungus was added. In making these inoculations it was found that much depends upon the moisture conditions. For example, branches in the orchard inoculated with Glomerella in July, 1909, did not become infected while the same branches inoculated with this fungus in May, 1910, when there was more moisture and more active growth of the wood showed a well marked attack before the end of the season. It is rather difficult in making a series of inoculations to provide conditions which correspond to the natural conditions in the orchard and still conform to the requirements of work with pure cultures under such control that the conclusion can be drawn that the disease is caused by the organism used. In natural infection rather large wounds

may occur which remain open for a considerable time and the fungus spores may be carried to the wound, the tissues around which have become somewhat broken down, at a time when the weather conditions are most favorable for infection.

An effort was made to overcome some of these difficulties. In making inoculations an incision was made through the bark with a scalpel sterilized by heating. A small amount of material consisting of mycelium, or in some cases of mycelium and spores of the fungus was placed in the incision and the wound was then wrapped in moist absorbent cotton. In a number of cases when the young trees in the greenhouse were used they were placed in a moist chamber for a few days. In no case did a diseased area develop from a check incision.

May 13, 1909, five of the one year old Baldwin trees in the greenhouse were inoculated with *Sphaeropsis malorum* using material from a young prune agar culture of the fungus isolated from leaf spot in the summer of 1908. These trees were each inoculated in from 3 to 5 places in the stem and branches. Each wound was wrapped in moist cotton which was kept moist for one week. At the end of that time examination showed that the fungus was growing and attacking the bark at every point of inoculation except one. June 2 it was found that the diseased areas were spreading and in one tree the upper branch was girdled and the leaves were beginning to wilt. This tree was dead June 22 but none of the others were girdled so soon. On August 6, another of the trees was dead as a result of girdling. In most cases the spreading of the diseased areas was checked by the formation of callus so that the bark was killed in a strip 2-8 cm. long on one side of the stem or branch. Other inoculations with Sphaeropsis gave similar results.

The results of inoculations with *Coryneum foliicolum* and *Phoma mali* have been given in detail in another publication[1]. It was found that each of these fungi caused well marked diseased areas in the bark of young trees and the young branches of orchard trees upon inoculation. In trees inoculated with Sphaeropsis and Coryneum on the same date the diseased areas spread at about the same rate and in each case part of the trees or branches were killed and in part the growth of the fungus was checked by the formation of callus. The writer was convinced by the results of inoculations with Coryneum and Phoma as compared with Sphaeropsis under the same conditions that these two fungi are capable of causing considerable damage to young apple trees and small branches but they do not seem to attack old branches so strongly as Sphaeropsis.

[1] Me. Exp. Sta. Bul. 170. 1909.

Some inoculations were also made with *Glomerella rufomaculans* using material from pure cultures of the fungus which was isolated from an apple purchased from a store in Orono. This fungus agreed in cultural characters with the southern form as described by Edgerton[1]. Seedling trees, 1-year old, budded trees, and branches of trees in the orchard were inoculated. The effect of the fungus on these different trees is of interest for comparison with other fungi.

May 31, 1909, 2 of the 1 year old budded trees which had been growing in the greenhouse since early in the spring were inoculated and July 13, 4 additional trees were inoculated. The fungus spread quickly into the uninjured tissues and all of the trees were killed in about one month from the time of inoculation. Perithecia developed in the dead bark in rather large numbers and many of these were found to contain mature asci when the trees inoculated July 31 were examined August 17.

A number of inoculations were made in branches of orchard trees in July, 1909. The weather was hot and dry for several days following and the fungus did not grow in any case. May 12, 1910, the same branches were inoculated again and this time a diseased area was produced in each case.

May 6, 1910, 5 places were inoculated in seedlings a little more than one year old. The fungus caused small, diseased areas in these trees but did not kill them. They seemed more resistant than the budded trees used in 1909. Some of these seedlings were also used with Sphaeropsis and Coryneum in May, 1910, and these fungi did not attack them so readily as they attacked the grafted trees and the orchard trees in 1909. This form of Glomerella seemed to be the most active parasite of any of the fungi used in these experiments.

Inoculations were made on the grafted trees in the greenhouse during the spring of 1909 to determine whether certain other fungi were parasitic on the wood and in each case with negative results. The fungi used were: *Phyllosticta limitata*, *Coniothyrium pirina*, 3 undetermined fungi from diseased leaves, Epicoccum sp., and *Cylindrosporium pomi* Brooks. None of these fungi spread into the uninjured tissues to cause disease although the inoculations were made under exactly the same conditions as those with Sphaeropsis, Coryneum, etc.

In the spring of 1910 two other fungi which had been isolated from diseased apple branches were tested by means of inoculations. These two fungi *Myxosporium corticolum* Edgerton and a species of Cytospora

[1] Edgerton, Claude Wilbur. The physiology and development of some anthracnoses. Bot. Gaz. **45**: 405. 1908.

occur so frequently on twigs and small branches which have died back as to almost force one to the conclusion that they are parasitic.

Myxosporium corticolum has been confused in many cases with *Sphaeropsis malorum*. Edgerton's[1] study of the fungus has shown that when sections of the fruiting pustules are examined it is very easy to determine that this fungus is not closely related to Sphaeropsis.

The spores of Myxosporium germinate readily enough in prune agar but the mycelium grows slowly. On bean pods the mycelium is white in color. About 2 months after transfers were made from plates to bean pods the fungus fruited and produced many spores identical in shape and size with spores from the pustules on apple branches.

May 6, 1910, 9 places were inoculated in seedling trees one year old. The incisions were wrapped in moist absorbent cotton which was kept moist for several days. The fungus did not cause disease of these trees but this could not be regarded as very conclusive evidence because they were found to resist attacks by other fungi which are known to be parasitic.

Inoculations were made in small branches in the orchard May 12, 1910. Sphaeropsis and Glomorella were also used as checks on the same trees. On one branch inoculated with Myxosporium the typical killing back which is characteristic of branches on which this fungus so frequently occurs was found. Other branches failed to show any injury whatever due to the inoculations, so it is questionable whether the injury in this case was due to that cause. On one branch 4 places were inoculated with Myxosporium and 2 places with Sphaeropsis. When they were examined July 27, Sphaeropsis had almost girdled the branch in both places while Myxosporium had not invaded the uninjured tissues. On another branch, 4 places inoculated with Myxosporium caused no disease while 3 places in which Glomerella was used showed well marked attack of the uninjured bark.

The dying back of young branches is probably due in many cases to other causes than attacks of the branches themselves by parasitic fungi even when they appear to have been killed by parasites. Some branches may be so weakened by winter injury that although they are not killed outright they may be attacked by fungi which would not be able to cause the death of healthy branches. In some cases too it is very probable that branches die back on account of poor nutrition of the trees.

In the summer of 1910, the writer visited an orchard in which the trees were set closely, the land had not been cultivated for several

[1] Edgerton, C. W. Two little known Myxosporiums. Annales Mycologici 6:47-52. 1908.

years and was covered with a close sod. There were so many trees that showed a dying back of the branches up to 2 inches in diameter that the owner felt that his orchard would soon be dead. The only fungus which occurred constantly on these branches was *Myxosporium corticolum*. There was very little of the canker which is caused by *Sphaeropsis malorum*.

In the light of the results of inoculations with this fungus the writer does not believe that Myxosporium was the sole cause of the killing back but it does seem probable that the fungus could attack the weakened branches and thus hasten their death, giving the appearance that they had been killed by a more active parasite than this fungus seems to be.

In another orchard, a small branch was observed which had died back for a distance of about 3 feet in one summer. This branch appeared identical with those on which Myxosporium is so frequently found although the fruiting pustules had not yet developed. The tree seemed to be in fairly good condition but later in the fall it was blown over and then it was found that the heart wood was almost destroyed by wood decay fungi. There can be no doubt that this had weakened the branches and made them susceptible to attack by fungi.

A species of Cytospora occurs very frequently on small dead branches in Maine orchards. Pure cultures have been made from material from orchards in Orono and Monmouth. On the twigs from Monmouth the perithecia of a Valsa were found. Plate cultures were made using the ascospores. When the colonies from the ascospores had developed sufficiently they were transferred to plates of prune agar. The colonies spread over the entire surface of the plates in 10 days. Very little aerial mycelium developed. Bean pod tubes produced mature pycnidia with a great many of the small curved Cytospora spores 2 weeks after transfers were made from the plates. The appearance of the cultures from ascospores was identical with cultures from the Cytospora spores from both Monmouth and Orono, showing that the Valsa is the perfect form of the Cytospora. From the measurement of the spores and asci this fungus agrees quite closely with *Valsa leucostoma* (Pers.) Fr. The perithecia have never appeared in my cultures.

Some of the one-year-old seedling trees were inoculated May 6, 1910, with the material from a culture growing on sterilized apple wood in tubes. The fungus did not spread into the uninjured bark to cause disease. May 12, 10 places were inoculated in small branches in the orchard. Other places in the same branches were inoculated with Sphaeropsis for comparison. When these branches were examined

July 27, it was found that Cystopora had not caused disease while each place in which Sphaeropsis was used showed a diseased area.

The results of these tests lead to the conclusion that the Cytospora which occurs on apple twigs in Maine is not an active parasite and cannot attack living healthy bark. It may be possible, however, that it can gain entrance into twigs which have been weakened from some other cause and by its growth hasten their death as seems to be the case with Myxosporium.

SUMMARY

A part of the leaf spot which occurs in Maine orchards is due to the growth of a parasitic fungus, *Sphaeropsis malorum*, but a similar spotting due to spray injury is found in orchards which have been sprayed with bordeaux mixture.

Sphaeropsis is the only fungus isolated from apple leaves in the state which causes spots on leaves when inoculations are made from pure cultures.

Phyllosticta limitata, *Coniothyrium pirina*, and *Coryneum foliicolum* grew and fruited on dead spots when the spores were sprayed on the leaves but no new spots were produced.

These fungi and several others occur on dead spots in apple leaves in July and it is often impossible to determine from an examination of the leaves whether the original cause of the spotting was spray injury or the attack of Sphaeropsis.

A number of fungi occur on branches and twigs of the apple in Maine. Of these Sphaeropsis does the greatest damage but it has been proved by inoculation experiments that Coryneum and Phoma can cause considerable injury to young trees and branches of orchard trees. Myxosporium and Cytospora do not attack healthy branches but it seems probable that they attack weakened branches.

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APPLE FRUIT SPOT AND QUINCE BLOTCH

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(WITH PLATES IV AND V)

The following paper includes a second report upon the fruit spot of apples and a discussion of a similar disease of quinces.

Historical. The literature bearing upon the apple fruit spot was noted in an earlier report[1]. Halsted[2] seems to have been the first to describe the quince blotch in the United States. He speaks of it as an obscure disease and gives the following description. "There is no decay, in the ordinary sense, connected with it, but the fruit when only partly grown becomes blotched with black. This retards the growth of the immediate portion of the fruit, and soon the quince shows irregular depressions corresponding with the areas covered by the dark development. A fungus is constantly associated with this blotching, and by isolation it was found to grow upon a colorless jelly called agar and produce spots that corresponded in outline with those upon the quince. The structure and manner of development of this fungus is very different from anything previously mentioned upon the quince, and on account of its extremely slow growth it is not easy to experiment with. The pure virus of the blotch removed from the culture tubes and introduced into holes and cuts in healthy fruit will produce the first indications of the blotching, but in a few days some other germs find entrance and the experiment must close. However, the instances were repeated, and in some cases the results were sufficiently pronounced to warrant the conclusion already given. The fungus when grown upon sterilized solid substances kept free from germs produced the characteristic black color." The above description, together with an accompanying photograph of an affected quince, and one of the fungus growing on agar, leaves no doubt as to the identity of the disease in question.

From the time of the above description (1892) till the summer of 1910, there is apparently no record of the occurrence of the disease. During the fall of 1910 it was observed on Orange quinces at Stratham, N. H., by the writers. In the report of the Connecticut Experiment Station, issued June, 1911,[3] Clinton reported an instance in which a fungus, which he considered identical with the Cylindrosporium from the fruit spot of apple, was isolated from a market quince.

[1] Brooks, Charles. Fruit spot of apples. Bulletin Torrey Botanical Club, **35**: 423–456. 1908. (Or Scientific Publication No. 2, N. H. Agr. Exp. Sta. 1908.)

[2] Halsted, B. D. Some fungous diseases of the quince fruit. N. J. Agr. Exp. Sta. Bull. 91: 13. 1892.

[3] Clinton, G. P. Conn. Agr. Exp. Sta. Rep. Part x. **1909–10**: 724.

Occurrence. During the past summer the quince blotch has been found on fruit from Maine, Massachusetts, Rhode Island, Connecticut, and from various sections of New Hampshire. The disease has been common on the quinces offered for sale in the Boston markets the past season and has been frequently noted on those competing for prizes at fruit shows. The Orange quince seems to be particularly susceptible, but the disease occurs upon nearly every variety of *Cydonia vulgaris* grown in New England.

The fruit spot of apples is of general occurrence in New England, is a serious disease in Maryland, and has been found on apples from Pennsylvania, New York, Michigan and Canada. It is particularly bad on Tolman Sweets and Baldwins but has been found on more than twenty varieties of apples.

GENERAL CHARACTERISTICS

The quince blotch appears on the fruit in late August or early September. The spots are from one to five millimeters in diameter. They are usually slightly sunken and the large ones are often decidedly so, but the tissue of the spots is always firm. The spots are a darker green than the surrounding tissue, and have minute black specks scattered thickly over them (Pl. IV, Figs. 2 and 4). These specks are often so thick that they give the center of the spot an almost uniformly black appearance. Such a condition is shown in Plate IV, Fig. 3. The spots occur on various parts of the quince but are most numerous near the blossom end. Here they often unite, sometimes forming one continuous blotch. When the fruit is allowed to dry until it becomes wrinkled the spots remain smooth and, instead of being depressed, as at first, now form rather firm elevations. The spots remain practically the same in storage, making but little development and never showing any sign of a general softening of the tissue.

The spots on the apple have been rather fully described in the first report upon the disease. The appearance of the early stages is much the same as on the quince but the black specks in the spots are not as large nor as numerous (Pl. IV, Figs. 1 and 5). The intensity of the coloring of the spots is always greater than that of the surrounding tissue, being a darker green on light portions of the fruit and a deeper red on the colored areas. As the apple matures in storage the spots often change to a brown or black and the tissue may become soft and shrunken as in the beginning of a rot. The spots often have an appearance almost identical with that of the first stage of the Sphæropsis rot.

On very ripe apples brown, rot-like areas more than a centimeter in diameter are often found. These appear to have developed from a

single spot as a center. Dark pycnidia develop beneath the epidermis in these areas. They are often arranged in the form of a circle. They are evident in a surface view, both by their color, which shows through the epidermis, and by the elevations which they produce.

With the exception of late stages of the disease on apple, sections of spots show practically identical conditions on the two hosts. The tissue of the spots is darker and the cells near the surface are smaller and thicker walled than the corresponding healthy cells. The specks seen in the surface view are found to be due to the groups cells in the sub-epidermal region, which have very heavy walls and contain dark cell contents (Pl. V, Fig. 12). In these cells the starch content is large and the protoplasm often very dense. The most destructive effects, however, are found beneath this zone in the large isodiametric cells of the fruit pulp. This tissue seems less able to resist the attack of the fungus, and several adjacent cells are often completely collapsed, thus producing pockets in the tissue (Pl. V, Fig. 12). The mycelium of the fungus is quite evident in these pockets. The hyphae are coarse and septate, but finer threads extend from them into the surrounding tissue. These finer hyphae are hyaline, non-septate and their contents are slightly granular. Chlamydospores are not uncommon on the coarser hyphae. The mycelium is usually intercellular but sometimes intracellular. The fungus has sometimes been found in the sub-epidermal specks described above. When present in these the hyphae are very fine and only detected by the most careful staining. These specks are one of the most striking characteristics of the spots.

In late stages of the disease on apples the cells of the host are brown and collapsed. In some cases the browning of the tissue extends down the vascular bundle, but this may be due to the over-ripeness of the apples and coincident with the maturing of the spot, rather than caused by the presence of the fungus in the tissue.

Chromo-acetic, picro-acetic and picric acids were used as fixing agents. All of these gave satisfactory results. In staining, Bismarck brown, followed by gentian violet or methylene blue, was found very satisfactory. A good contrast between host and fungus was secured and the method is a quick one.

THE FUNGUS IN CULTURE

Affected quince tissue, when transferred to sterile media, invariably gave pure cultures of a fungus, apparently identical with that from the fruit spot of apples. Blocks of affected tissue in liquid media were soon fastened to the bottom of the test tube by the mycelium.

After spores had been produced and had been distributed through the medium, numerous colonies developed on the walls of the test tube or flask. These fungous masses were hemispherical in shape and were composed of anastomosing hyphae that radiated from the point of attachment. The tenacity with which these colonies clung to the bottom and sides of the vessel was a very striking characteristic of the fungus (Pl. IV, Fig. 6.)

Conidia were produced abundantly on most media. They were hyaline, slender and had from one to five cells. They were straight, curved or sigmoid and measured $20-50 \times 2-3\ \mu$ (Pl. V, Fig. 11). They were cut off from knob-like projections on the sides of the hyphae. The older spores were pushed to one side by younger ones developing from the same point, and an apparently indefinite number of spores would originate from one of these knob-like projections.

In all of these characteristics the fungus from the quince was identical with that from the apple. It was thought possible, however, in spite of their striking similarities, that the fungi from the two hosts might be physiologically different and distinct. In order to obtain further information on this point the growth of the two was tested on various culture media. No difference was found. Both liquefied gelatin. Inoculated potato strips were blackened by both fungi. Beef bouillon when inoculated with either fungus became very dark after seven to ten days. Both fungi turned litmus milk red and then a dark brown. About five days after inoculation a zone of clear red would appear in the upper part of the test tube, in striking contrast to the litmus colored milk below. This would gradually move downward, always separated from the unchanged milk by a definite line and always followed by the dark brown color.

It seemed probable that an enzyme might play a part in the browning of various culture media and also in the effects of the fungi upon the hosts. Beef bouillon in which the fungi had been growing for two weeks, and which had become dark from their action, was tested for the presence of oxidases with the following results: The addition of guaiacum gave no color reaction, whether used alone or with hydrogen peroxide, indicating the absence of oxidase and peroxidase. The addition of hydrogen peroxide, however, gave a positive test for catalase. This reaction was strong in the older cultures of both fungi but weak in those which had not yet turned the medium dark. To test the comparative catalase-producing power of the two fungi, 30 cc. of beef bouillon were added to each of eight 100 cc. flasks and half of these inoculated to excess with the apple fungus and the other half similarly inoculated with the quince fungus. After 30 days the

cultures were filtered through filter paper and the filtrates tested for catalase after the method used by Appleman.[1] One cc. of 3 per cent. hydrogen peroxide and 5 cc. of water were added to each 5 cc. of bouillon and records made of the amount of gas evolved. In five minutes .6 to .9 cc. of oxygen were given off, the amount varying with the individual culture. Increasing the amount of hydrogen peroxide gave little or no increase in the amount of oxygen. The average quantity of oxygen evolved by the quince fungus cultures was slightly greater than that from the apple but the difference was not great enough to be significant.

Experiments were made to determine what effects could be produced upon culture media by the enzyme alone. Beef bouillon in which the fungi had been growing for three months was filtered through filter paper and then tested with hydrogen peroxide. It was found to be quite strong in catalase. A part of this bouillon was sterilized in an Arnold sterilizer and portions of it added to neutral litmus milk tubes and enough 95% alcohol added to make a 15% solution. Proportionate amounts of the unsterilized bouillon were added to other litmus milk tubes and also enough alcohol to make the solution 15% alcoholic. Boiling destroyed the catalase, while a 15% alcoholic solution prevented fungous action without destroying the enzyme. At the end of seven days no change had occurred. Tests with hydrogen peroxide showed that the strength of the enzyme had not been weakened. The action of the catalase was similarly tested upon potato strips, but with negative results. The catalytic enzyme of the fungus is evidently not responsible for the blackening of culture media produced by the fungus.

CROSS INOCULATIONS

Although the structural, as well as the cultural, characters indicated that the fungi from the two hosts were the same, it was thought essential to make cross inoculations before a final decision was made in regard to their relationship. No quinces could be readily secured for the work, so the experiments were confined to tests made upon Baldwin and Tolman Sweet apples. A large number of liquid cultures were kept in stock and the spores from these were applied to the fruit by means of an atomizer. All inoculations were made after four o'clock and as far as possible on cloudy, or damp days. Inoculations with the two fungi were always made on the same day. The cultures of the two fungi used for a particular inoculation were of

[1] Appleman, Chas. O. Some observations on catalase. Bot. Gaz. **50**: 182–193. 1910.

approximately the same age, and were alike in other respects. Forty twigs scattered over five Tolman Sweet trees and twenty twigs scattered over two large Baldwin trees were used in the inoculation work. Each twig had from four to seven apples on it. The fruit on half of these twigs was sprayed with the spores of the apple fungus, and the fruit on the other half with the spores of the quince fungus. Each set of twigs received ten sprayings. These sprayings were made between July 13 and August 8 inclusive. Twigs similar to those used for inoculation were taken as checks. On September 16 the Tolman Sweets inoculated with the apple fungus were thickly spotted with minute green specks, while those inoculated with the quince fungus were almost free from spots. The following table gives the average number of spots per apple at the time of gathering.

	Tolman Sweet, Sept. 28	Baldwin, Oct. 3
Sprayed with apple fungus	54.1	8.4
" " quince "	10.3	1.5
Checks	3.0	1.4

At the time of taking these notes there were a considerable number of specks on the fruit that could not be definitely classed as true spots. These were especially common on the Tolman Sweets inoculated with the quince fungus. The apples were all placed in cellar storage and a second count was made of the spots some weeks later with the following results:

	Tolman Sweets, Oct. 16	Baldwins, Nov. 10
Sprayed with apple fungus	121.3	30.1
" " quince "	47.5	4.7
Checks	7.9	1.2

The spots produced by the two fungi were alike. The smaller number of spots produced by the quince fungus, and their tardiness in developing, may have been due to some difference in the cultures used, although this was carefully guarded against. It is possible that this contrast was caused by a physiological difference in the two fungi due to the fact that the last host of one had been the quince and of the other the apple. Whatever the cause of this difference may have been the results obtained from cross inoculations, together with the data in regard to structural and cultural characters, leave no doubt but what the fungi from the two hosts should be considered as one and the same species.

PHOMA STAGE

In the work described in the earlier report upon the apple fungus, a Cylindrosporium stage was found on the fruit, and considerable evidence of a pycnidial form was obtained, both from the apple and from cultures. Since then the fungus has been grown upon a large

variety of media in an effort to mature these pycnidia in culture. Fair results were obtained on apple twigs. The amount of moisture seemed to be an important factor. These facts led to growing the fungus on apple twigs that were partly immersed in various substances. Among these were a 2% sugar solution, slightly moistened filter paper and moist loam, sawdust, and graham flour. Pycnidia were common but none matured. They sometimes developed on the surface of the bark but more often in the region of the cambium and inner bark. Since the work on the quince fungus has been in progress it has been grown on various media and has shown the same tendency to form pycnidia as cultures taken from apples. No difference could be detected between the pycnidia from the quince fungus and those from the apple fungus. With a few exceptions, the pycnidia from the various kinds of cultures were also alike.

On the stromata developed on sweetened apple decoctions the pycnidia were sometimes thimble-shaped but on all other media they were spherical or nearly so. They usually formed near the surface of a stroma but sometimes were deeply imbedded in the fungous mass. Where pycnidia were closely packed the walls were sometimes wanting at the point of contact. The walls were thick and composed of parenchyma-like cells. The outer cells were thick walled and brown, the inner were thinner walled and slightly larger. The centers were either empty or filled with a granular, hyaline substance. Figure 9, Plate V shows an immature pycnidium obtained by growing the quince fungus on sweetened apple solution. Later, these pycnidia often went through some change akin to bursting and a new growth would be made from the broken edges (Pl. V, Fig. 10.)

Apples and quinces have been stored under various conditions of moisture and temperature in efforts to secure other fruiting stages on the hosts. Chlamydospores have been common in the tissue of both hosts, and conidia have occasionally been found in the tissue of both. No pycnidial development has been obtained on the quince. Sclerotial masses and immature pycnidia have been fairly common on badly spotted over-ripe apples. Under moist conditions masses of short hyaline hyphae often arise from these sclerotial masses and from the immature pycnidia. These may rupture the epidermis at a stoma and are sometimes spore-bearing. The spores produced are like those obtained in culture, both as to origin and structure. In the earlier report on the fruit spot of apples this condition of the fungus was described as a Cylindrosporium stage. Further study of these pustules has shown a great variety of form and condition and would seem to indicate that they should be regarded as a new growth arising from

an old fungous mass rather than a typical fruiting body. This idea is supported by the behavior of the fungus in culture. The tendency of immature pycnidia to burst and start a new growth from the edge has already been noted. A similar behavior of mature pycnidia is described in a later paragraph. When the coarse mycelium of an old culture is transferred to Van Tieghem cells, each cell of the old hyphae may germinate like a spore, sending out a short hyaline thread that often becomes a sporophore. A considerable number of these hyphae, if closely packed together, would produce a condition similar to the Cylindrosporium stage previously described. Also, this stage has been obtained only from apples that have been kept under moist conditions such as would favor the development of a new growth from the old tissue.

In the winter of 1910–11 badly spotted Tolman Sweet apples were kept in cellar storage and the apples examined every two or three weeks for spots bearing pycnidia. By the latter part of March a number of typical fruit spots had developed unusually prominent elevations in the center. A microscopic study of these spots showed them to contain pycnidia of the usual form but mature and spore-bearing.

The apples used in the inoculation experiments of the summer of 1911 were placed in cellar storage and carefully examined the following winter. The spots became brown, sunken and much enlarged, sometimes having a diameter of more than a centimeter. In the small spots the pycnidia developed in the center, while in the large ones they were scattered. In some cases they were arranged in a ring .5 to 1 centimeter in diameter.

Either pycnidia, or tissue from these spots, when transferred to sterile culture media, developed a mycelium that produced the conidial stage already described. Crushed pycnidia in Van Tieghem cells, however, showed that the new growth came from the inner walls of the pycnidia and not from germinating spores. Various culture media have been used in attempts to germinate the spores but with only negative results. It is believed, however, that the spores can be made to germinate. This idea is supported by the fact that when apparently normal pycnidia have been transferred to liquid media, numerous colonies have sometimes developed on the walls of the test tubes in too short a time to have resulted from spores produced after the cultures were made.

The pycnidia may be solitary or in groups. They do not arise from a stroma. They are typically spherical but when crowded show a great tendency to conform in outline to the cavity in which they develop. (Pl. V, Fig. 8.) The pycnidia are ostiolate-papillate and measure

50–115 μ in diameter and 70–125 μ in height. The wall consists of two layers, both parenchymatous in structure, the cells of the outer having thicker walls and darker contents than those of the inner. The sporophores arise from the inner layer but apparently not from the innermost cells. (Pl. V, Fig. 8.) They develop on the side walls as well as at the base of the pycnidium. They are hyaline, short, and 8–1.0 μ in diameter. The spores are cut off from the tips of these, and are produced in large numbers. They have two obscure vacuoles. They are hyaline, non-septate and measure 2–3.5 x .8–1.0 μ.

The characteristics given above with the absence of a stage on the foliage, place the fungus in the genus Phoma. Retaining the species name first given, the name of the fungus would be *Phoma Pomi*. This name, however, has already been used by Passerini[1] to describe a fungus occurring on the fruit of *Cydonia sinensis*. The pycnidia under consideration bear a close resemblance to those described by Passerini. In his description he states that sporophores were not observed, while in the pycnidia examined by the writers the sporophores were present although inconspicuous. Passerini found the spores to be 5 x 1.5 μ while those reported above were 2–3.5 x .8–1 μ. The pycnidia described by Passerini, however, were from quince fruit, while those observed by the writers were from apples. The difference in host might account for the difference in spore measurements or even for differences in pycnidial structure. Until further evidence to the contrary is at hand the writers are inclined to consider the American species as identical with that of Passerini. With this construction of the matter *Cylindrosporium Pomi* Brooks becomes *Phoma Pomi* Passer. The following is Passerini's description of the fungus.

"*Phoma Pomi* Passer.—Perithecii in matrice albo-pulverulenta gregarii, pustuliformibus, tectis; ostiolo papillari, atro; sporulis cylindricis, hyalinis, obscure biguttulatis, 5x1.5; basidiis non visis. Hab. in fructu indurato Cydoniae sinensis. Vigheffio pr. Parmam Ital. bor."

CONTROL

As stated in the earlier report the fruit spot of apples is readily controlled by spraying. Applications made early in July are most efficient. No spraying experiments have been made on quinces. A case was observed the past summer of quince bushes that had received a dormant spray and that were located near others that had not been sprayed. The sprayed quinces had much fewer spots than the others. Since the disease develops at the same time of the year on quinces that it does

[1] Passerini, G. Diagn. F. N. IV, n 73.

on apples, and is of the same nature on the two hosts, it is to be expected that one or two sprayings on quinces made before the middle of July would entirely prevent the disease on this host.

SUMMARY

1. A Phoma stage has been found for the fungus causing the fruit spot of apples and the name of the fungus is thus changed from *Cylindrosporium Pomi* Brooks to *Phoma Pomi* Passer.

2. A spot similar to that on apples has been found on quinces, and cross inoculations have shown one fungus to be responsible for the disease on the two hosts. The quince disease was described by Halsted under the name of quince blotch.

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DESCRIPTION OF PLATES

PLATE IV

FIG. 1. Fruit spot on Tolman Sweet apple.

FIG. 2. Fruit spot on Orange quince.

FIGS. 3-4. Spots from Orange quince, magnified.

FIG. 5. A single spot from apple, magnified. The spot is the one indicated by the arrow in Fig. 1.

FIG. 6. A seven-day culture of *Phoma Pomi* in beef bouillon.

FIG. 7. A later stage of fruit spot on Tolman sweet.

PLATE V

FIG. 8. A mature pycnidium of *Phoma Pomi* from apple. The escaped spores may be seen in a mass at the mouth.

FIG. 9. An immature pycnidium from sweetened apple solution.

FIG. 10. A pycnidium from culture, that has resumed ordinary vegetative growth without maturing.

FIG. 11. Production of conidia.

FIG. 12. Section of quince tissue showing the effects of the fungus. The hyphae are shown in the pocket.

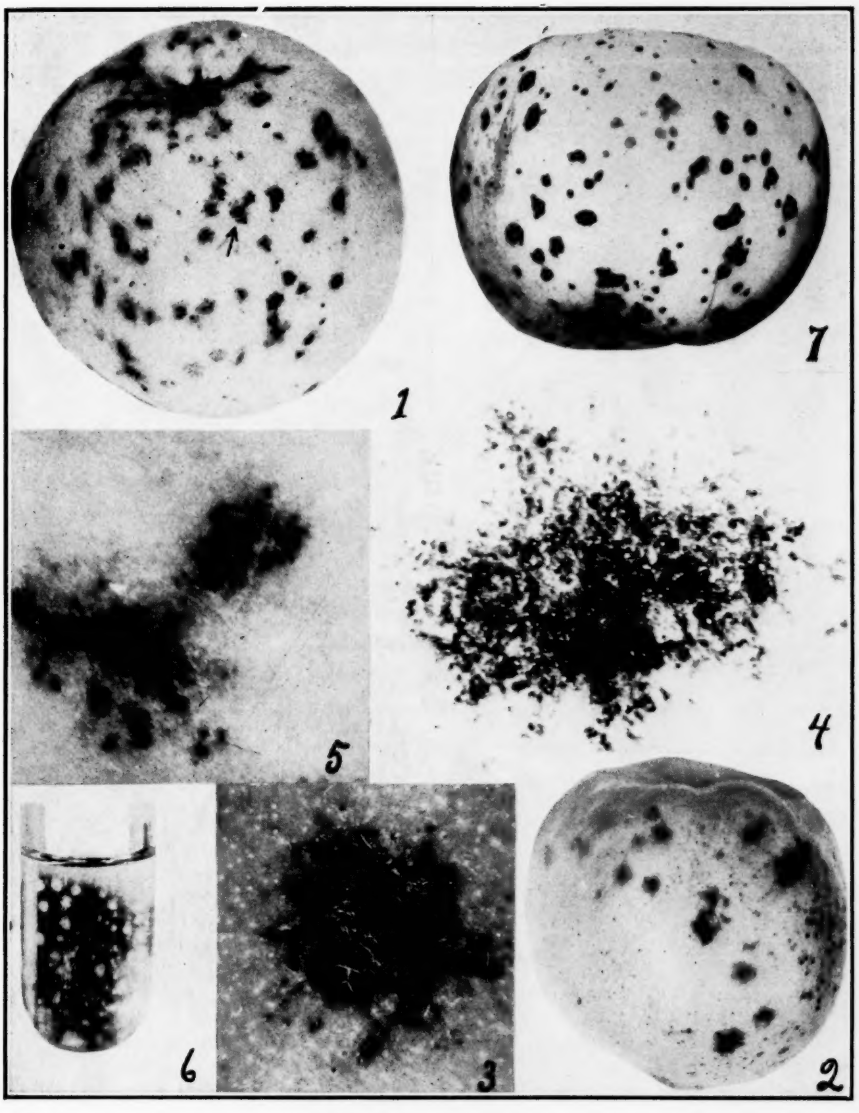

PLATE IV.—**Apple Fruit Spot and Quince Blotch**

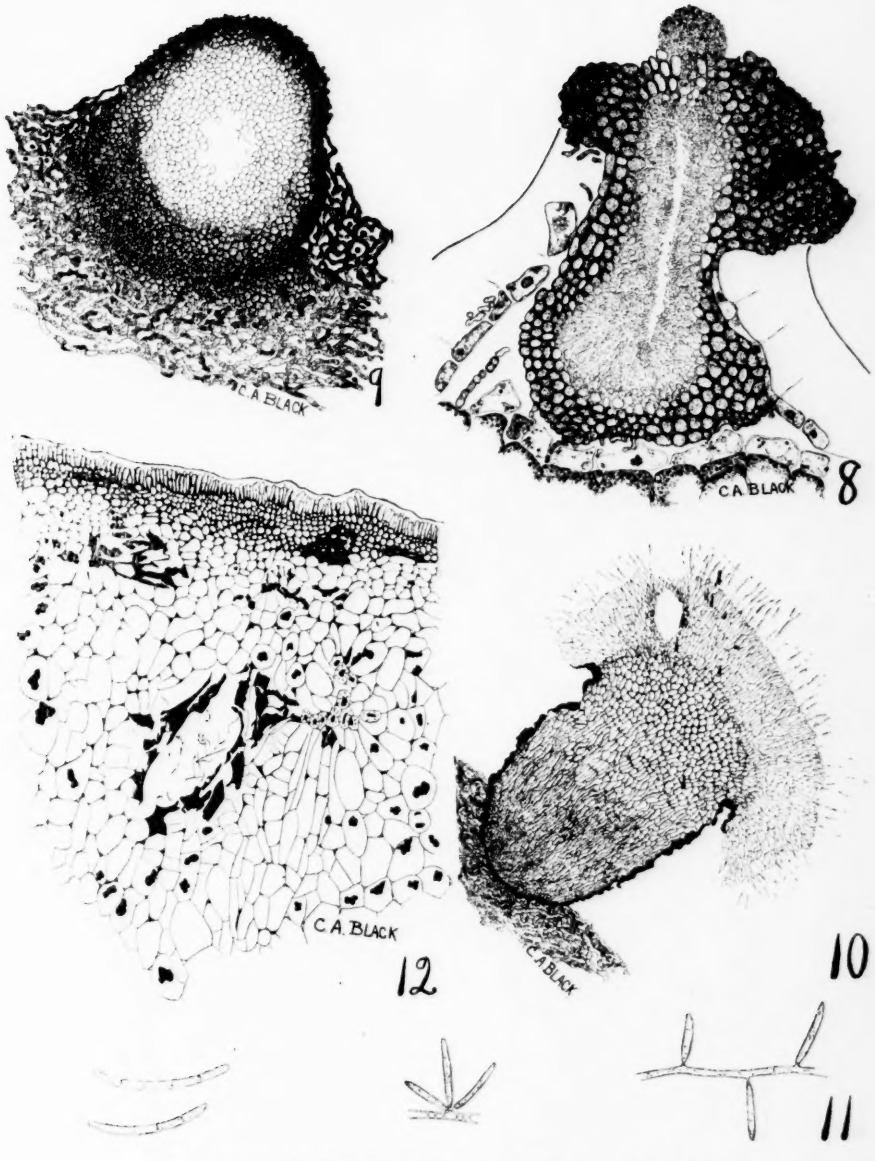

PLATE V.—**Apple Fruit Spot and Quince Blotch**

NOTES ON SOME DISEASES OF TREES IN OUR NATIONAL FORESTS. II[1]

GEORGE GRANT HEDGCOCK

The study of the prevalence of forest tree diseases in the west in connection with the Forest Disease Survey has been successful along several lines. Not the least important is the discovery of many new host species for the more common tree fungi, together with the data on the prevalence of the diseases they cause. In addition, some fungi hitherto considered of little economic importance have been found common disturbing elements to the health of the forests, not only in national forests but in private ones as well. The work of collecting data has not been confined to national forests, nor to the western United States, but extends to all of the principal forested areas of the United States.

In the enumeration of host trees in the following paper, the nomenclature followed is that used by Geo. B. Sudworth in the publications of the Forest Service[2] of this Department.

As a rule, the species of wood-rotting fungi attacking the broad-leafed deciduous trees in the United States do not commonly attack the coniferous trees, and the following notes will roughly separate the diseases caused by them into two classes according to the hosts usually attacked.

Owing to the large amount of data on hand it is impossible to give localities and names of collectors in case of each species of host and fungus. All data given are based either on specimens in the collections of the Forest Disease Survey at Washington, or on authentic notes in the files of the office. A more complete publication of data will probably be issued later by the Department of Agriculture.

I. DISEASES OF DECIDUOUS TREES

Polyporus dryophilus Berk. has been definitely proven to be associated with the piped rot of the heart wood of the oaks. This rot has been previously described by von Schrenk and Spaulding[3] and re-

[1] Published by permission of the Secretary of Agriculture.

[2] Forest trees of the Pacific Slope. U. S. Dept. Agric. Forest Service. 1908.

Nomenclature of the arborescent flora of the United States. U. S. Dept. Agric. Div. Forestry. Bul. 14. 1897.

Check list of the forest trees of the United States. U. S. Dept. Agric. Div. Forestry. Bul. 17. 1898.

[3] Von Schrenk, and Spaulding, P. Diseases of deciduous forest trees. U. S. Dept. Agric. Bur. Plant Ind. Bul. 149 : 39, 40, pl. V. 1909.

ported in the oaks and chestnuts, but the cause of the rot was not ascertained. The cause of the piped rot of the chestnut is yet to be determined.

Polyporus dryophilus is so prevalent on the oaks in many regions in Texas, New Mexico, Arizona, California, and Oregon that the trees are worthless for lumber or posts, and even of little value for fuel. In extreme cases the trees may be killed outright. The following species of oaks in the United States have been found diseased with the piped rot caused by this fungus: *Quercus alba*, *Q. arizonica*, *Q. californica*, *Q. emoryii*, *Q. coccinea*, *Q. gambelii*, *Q. imbricaria*, *Q. lobata*, *Q. lyrata*, *Q. macrocarpa*, *Q. marilandica*, *Q. michauxii*, *Q. minor*, *Q. nigra*, *Q. oblongifolia*, *Q. palustris*, *Q. phellos*, *Q. rubra*, *Q. texana*, *Q. toumeyii*, *Q. undulata*, *Q. velutina*, *Q. virginiana*, and *Q. wislizeni*. This disease is considered the most destructive heart rot of the oaks in the national forests and is very important elsewhere in the United States.

Second in importance to the heart rot of oaks caused by *Polyporus dryophilus* is that caused by *Fomes everhartii* (Ell. & Gall.) von Sch. & Spauld. This fungus causes a rot of oaks varying from brown to white with an outer darker colored area along the margin of the decayed portions. In red oaks where the wood is dark colored, the rot may be chiefly of a light brown color; in white oaks it is usually chiefly of a white color. The final effect of the disease is similar to that of *Polyporus dryophilus*. In both diseases the trees sometimes become hollow.

The following species of oaks are known to be attacked by *Fomes everhartii*: *Quercus arizonica*, *Q. coccinea*, *Q. digitata*, *Q. gambelii*, *Q. imbricaria*, *Q. macrocarpa*, *Q. marilandica*, *Q. nigra*, *Q. oblongifolia*, *Q. palustris*, *Q. prinus*, *Q. rubra*, *Q. texana*, *Q. undulata*, and *Q. velutina*.

This fungus is also the cause of the most common and destructive heart rot of walnut and mesquite trees. The rot caused by it in mesquite trees is usually brown, sometimes mingled with traces of white, giving it a slightly mottled appearance. The color of the rot in walnut trees is similar to that in oaks. *Juglans rupestris* suffers so much from this heart rot that older and mature trees in the southwest are commonly worthless for lumber or posts, and of little value for fuel. *J. nigra* and *J. californica* are frequently attacked, but trees of these species usually suffer less injury from the rot. *J. cinerea* is apparently rarely attacked, but data on this species are incomplete. *Prosopis juliflora* and its varieties are commonly subject to a heart rot caused by this fungus. Nearly all large mature trees are attacked in

many localities in southern Arizona. Other species of trees frequently attacked by this fungus are *Fagus atropunicea*, *Betula papyrifera*, and other species of birch. On deciduous trees in the western United States it outranks *Fomes igniarius* in economic importance because the species it attacks are more important and valuable than those attacked in the same region by the latter fungus.

Fomes igniarius attacks many species of trees in western and central United States, causing a well-known white rot with a brown or black margin next the outer sound wood resembling very much that of *F. everhartii*. In all of these species, except those of the oaks and walnuts, it is the principal cause of heart rot. The following species are known to be attacked: *Arctostaphylos* sp., *Acer glabrum*, *A. macrophyllum*, *A. pennsylvanicum*, *A. saccharum*, *A. saccharinum*, *A. spicatum*, *Alnus acuminata*, *A. oregona*, *A. rhombifolia*, *A. tenuifolia*, *Betula lenta*, *B. lutea*, *B. nigra*, *B. occidentalis*, *B. papyrifera*, *Castanopsis chrysophylla*, *Carpinus caroliniana*, *Cornus nuttallii*, *Fagus atropunicea*, *Juglans nigra*, *J. cinerea*, *Ostrya virginiana*, *Populus balsamifera*, *P. grandidentata*, *P. trichocarpa*, *P. tremuloides*, *Quercus garryana*, *Q. prinus*, *Q. marilandica*, *Q. rubra*, *Q. texana*, *Q. virginiana* *Salix bebbiana*, *S. lasiandra*, *S. nigra*, *S. nuttallii*, *Ulmus americana*, *U. racemosa*, and *Xanthoxylon* sp.

Polyporus (*Inonotus*) *texanus* (Murr.) also attacks the mesquite tree, *Prosopis juliflora*, in Texas. It causes a mottled brown and white heart rot. It is often found in connection with *Fomes everhartii*, the latter fungus usually attacking the heartwood of the lower portions of the trunk, and the former the upper portions and limbs.

The sporophores of *Polyporus texanus*, though somewhat hard and woody, are usually annual, but occasional ones were found that had formed two or three layers, and had evidently grown as many seasons.

Fomes nigricans Fr. of the form described by von Schrenk and Spaulding[1], where found on species of Betula in Minnesota, is apparently an abortive form of *Fomes everhartii*. It causes a rot apparently identical with that produced by the latter fungus. The interior structure of the abortive sporophores also resembles that of *F. everhartii*. The general absence of a pore layer in such sporophores makes the determination of the species necessarily uncertain.

Fomes applanatus (Pers.) Wallr. has rarely been found fruiting on living trees. This tends to verify the view of von Schrenk and Spaulding[2] that this fungus does not cause a disease in the sense that the rots produced by *Fomes igniarius* and *F. fraxinophilus* Peck. are diseases.

[1]loc. cit. p. 42.
[2]loc. cit. p. 59.

Fomes applanatus attacks readily both sap and heartwood, entering the sapwood on dead exposed roots or in dead areas at the base of trees. It attacks both deciduous trees and conifers, more rarely the latter, and has been found on the following species: *Abies concolor*, *A. grandis*, *A. lasiocarpa*, *A. shastensis*, *Acer macrophylum*, *A. saccharinum*, *A. saccharum*, *A. spicatum*, *Alnus oregona*, *Betula occidentalis*, *B. populifolia*, *B. lutea*, *Fagus atropunicea*, *Fraxinus* sp., *Hicoria* sp., *Liriodendron tulipifera*, *Morus alba*, *Picea canadensis*, *P. engelmanni*, *Populus acuminata*, *P. angustifolia*, *P. balsamifera*, *P. deltoides*, *P. grandidentata*, *P. tremuloides*, *P. trichocarpa*. *Pseudotsuga taxifolia*, *Pyrus rivularis*, *Quercus alba*, *Q. coccinea*, *Q. emoryii*, *Q. macrocarpa*, *Q. rubra*, *Q. palustris*, *Salix* spp., *Robinia pseudacacia*, *Tilia americana*, *Tsuga canadensis*, *T. heterophylla*, and *Umbellularia californica*. In case of the aspens (*Populus tremuloides*), *Fomes applanatus* often follows *Fomes igniarius*, rotting the base of trees that apparently have died from the effects of the latter fungus.

It has been found fruiting on dead areas at the base of living trees of the following species: *Liquidambar styraciflua*, *Pyrus malus*, *Morus rubra*, *Populus tremuloides*, *P. trichocarpa*, and *Quercus rubra*.

Fomes fasciatus (Sw.) apparently attacks old and mature living trees of *Hicoria pecan*, *H. aquatica*, *Platanus occidentalis*, *Magnolia foetida*, and *Quercus* sp. in southern United States. It causes a yellow to light-brown sap and heart rot, and it may be found that it acts much in the same manner as *Fomes applanatus*, in that it attacks only trees that have been killed or seriously injured by other causes.

Polyporus sulphureus Fr. is one of the well-known heart-rotting fungi attacking species of oaks and other trees, causing a red-brown rot which breaks up into small cubes. The gross appearance of the rot in oaks resembles somewhat the heart rot of conifers caused by *Polyporus schweinitzii* Fr. It has been found attacking the following species of deciduous trees: *Acer* spp., *Castanea dentata*, *Celtis mississippiensis*, *Gleditsia triacanthos*, *Juglans nigra*, *J. cinera*, *Robinia pseudacacia*, *Liriodendron tulipifera*, *Quercus californica*, *Q. chrysolepis*, *Q. coccinea*, *Q. gambelii*, *Q. garryana*, *Q. lobata*, *Q. macrocarpa*, *Q. platanoides*, *Q. rubra*, and *Q. wislizeni*.

Fomes fraxinophilus Peck causes the most important heart rot of species of ash. It attacks *Fraxinus americana*, *F. lanceolata*, *F. velutina*, and *Fraxinus* spp. It occurs very commonly on *F. velutina* in Arizona and New Mexico.

Fomes robiniae Murrill causes a heart rot of *Robinia pseudacacia* in the Mississippi valley and the eastern states, and of *Robinia neo-mexicana* in the southwestern states. In the latter species the rot often

extends through the heart and sapwood, affecting the growth of the cambium layer in irregular longitudinal bands so that the trunks grow angular and irregular in shape. This species of tree is rendered worthless by this fungus in most localities in New Mexico and Arizona.

2. DISEASES OF CONIFEROUS TREES

The natural forests of the greater part of the western United States consist almost entirely of coniferous trees. The annual loss from wood-rotting fungi in the national forests amounts to a very large item. An average of 2 to 10 per cent. of the mature trees in all the forests are attacked and rendered worthless. In some localities certain species, for example *Pinus monticola*, *Tsuga heterophylla*, *Abies grandis*, *A. lasiocarpa*, and *Pseudotsuga taxifolia* suffer to the extent of 50 to 75 per cent. of the total stand in board feet.

The most destructive disease of the heartwood of conifers is caused by *Trametes pini* (Brot.) Fr. This fungus is not equally prevalent in all localities on the same species. It probably attacks nearly all species of conifers in the United States, except the junipers. The progress of the rot through the tree trunks is not very rapid, but the final effect is certain, as in the end it usually destroys the whole heart of the trunks and of portions of the limbs. In some instances trees are killed outright, but in the majority of cases they are so weakened by the fungus that they are broken off by the wind. This fungus rots the heartwood of the roots also, and apparently is communicated from tree to tree underground where large roots of separate trees are in direct contact, thus passing from a diseased root to a healthy one.

The following species of trees are attacked by *Trametes pini* or its subspecies: *Abies balsamea*, *A. concolor*, *A. lasicocarpa*, *A. nobilis*, *Larix laricina*, *L. occidentalis*, *Picea engelmanni*, *P. mariana*, *P. rubens*, *P. sitchensis*, *Pinus contorta*, *P. echinata*, *P. edulis*, *P. flexilis*, *P. lambertiana*, *P. monticola*, *P. palustris*, *P. ponderosa*, *P. resinosa*, *P. rigida*, *P. strobus*, *P. strobiformis*, *P. taeda*, *P. virginiana*, *Pseudotsuga taxifolia*, *Thuja plicata*, *Tsuga canadensis*, *T. heterophylla*, and *T. mertensiana*.

Polyporus schweinitzii Fr. ranks next in importance to *Trametes pini* in the national forests. It commonly attacks the heartwood of the base of the trunk and of the roots of coniferous trees, especially of the Douglas firs. The rot rarely extends farther up the trunk than the first saw log. The fungus spreads from diseased trees to healthy ones underground, where larger roots come in contact with each other. Where this takes place it is common to find groups of trees affected with the fungus, and sometimes an entire group of Douglas firs is

killed outright. In most instances, however, the trees weakened by the fungus are either uprooted or broken off by the winds before death.

The heart rot caused by *Polyporus schweinitzii* is of a red-brown color, breaking into coarse cubes, and has been found in the following species of trees: *Abies amabilis, A. arizonica, A. balsamea, A. concolor, A. grandis, A. lasiocarpa, A. shastensis. Larix laricina, L. lyalli, L. occidentalis, Picea engelmanni, Picea sitchensis, Pinus albicaulis, P. aristata, P. arizonica, P. contorta, P. divaricata, P. echinata, P. flexilis, P. lambertiana, P. monticola, P. murrayana, P. palustris, P. ponderosa, P. resinosa, P. strobus, P. strobiformis, P. taeda, P. virginiana, Pseudotsuga taxifolia, Tsuga mertensiana*, and *T. heterophylla.*

A heart rot apparently identical with that caused by *Polyporus schweinitzii* is found in the following species of trees upon which the sporophores of the fungus have never been found: *Juniperus monosperma, J. pachyphloea, J. scopulorum. J. utahensis, Taxus brevifolia*, and *Thuja plicata.* However, this rot may be caused by *Fomes roseus.*

Fomes laricis (Jacq.) Murr. is the cause of a yellow to red-brown heart rot of living and dead trees of a number of species of conifers in the west. In the northwest it causes a common heart rot of larches, and in the southwest, of some species of pines. It is known to attack the following species of trees: *Abies concolor, Larix occidentalis, Picea engelmanni, P. sitchensis, Pinus lambertiana, P. murrayana, P. ponderosa, Pseudotsuga taxifolia*, and *Tsuga heterophylla.*

In northern Arizona, *Pinus ponderosa* is diseased more often with this than any other fungus.

Echinodontium tinctorium E. & E. is the cause of a very interesting heart rot of living trees of a number of species of conifers. In the earlier stages of the rot, the wood is slightly discolored, and often becomes very wet. The fungus attacks first the spring wood of each annual ring, causing the wood to separate into flakes. Finally, the wood is for the greater part dissolved and left in a yellow or brown stringy mass, often leaving the trees hollow.

The following species of trees are attacked by *Echinodontium tinctorium: Abies amabilis, A. arizonica, A. concolor, A. grandis, A. lasiocarpa, A. magnifica, A. nobilis, Picea engelmanni, Pseudotsuga taxifolia*, and *Tsuga heterophylla.* It is very destructive of the wood of hemlock trees in the northwest, and of species of *Abies* wherever found throughout the west. It is not infrequent to find 50 to 90 per cent of mature trees diseased by it and rendered useless for lumber or timbers.

A rot similar to the one produced by *Echinodontium tinctorium*, but unaccompanied by sporophores, occurs occasionally in *Pinus ponderosa*, *Pinus contorta*, and *Thuja plicata*. In general, however, the fungus fruits on species of Tsuga and Abies, and on these hosts almost to the exclusion of other heart-rotting fungi, where, in case of attacks by *Trametes pini*, infection apparently takes place later in the life of the tree, and the former fungus is enabled to inhabit the heart to the exclusion of the other.

Polyporus sulphureus (Bull.) Fr., or a form of this species, causes a red-brown rot of conifers, attacking both heart and sap wood. The rot caused by it is of a red-brown and resembles very much in color and appearance that caused by *Fomes laricis*, and to some extent that caused by *Fomes pinicola* (Sw.) Cooke. It is rarely found fruiting on living conifers. The wood of the following species is attacked by *Polyporus sulphureus*: *Abies grandis*, *A. magnifica*, *Larix occidentalis*, *Picea engelmanni*, *Pinus contorta*, *P. monticola*, *P. ponderosa*, *P. jeffreyi*, *Pseudotsuga taxifolia* and *Tsuga heterophylla*.

Polyporus amarus Hedgc. is the cause of the pin rot or peckiness of the incense cedar (*Libocedrus decurrens*) in Oregon and California. From 50 to 90 per cent. of the older trees in this region are affected to some extent by the fungus, causing a great loss in the wood products of this valuable tree.

A species of Lentinus, either identical or closely related to *Lentinus lepideus* Fr., attacks the heartwood of both living and dead conifers. It forms very large fruiting bodies on *Pinus ponderosa* in Arizona, and causes a yellow to red-brown rot much like that produced by *Fomes laricis*, but less extensive. It also attacks the wood of *Pinus contorta*, *Abies concolor*, *Larix occidentalis*, and *Pseudotsuga taxifolia*.

A species of Hydnum related to *Hydnum coralloides* Scop. attacks the wood of both living and dead trees of *Abies concolor*, *A. grandis*, *Picea engelmanni* and *Pseudotsuga taxifolia*. The fungus fruits in late autumn. It produces a peculiar honey-combed rot, in which there is an absence of cellulose layers around the small cavities as occurs in the rot caused by *Trametes pini*.

In general, the heart-rotting fungi in conifers enter the trees through exposed heartwood in broken branches, fire scars, etc., and do not attack the sapwood first. This is especially true of *Trametes pini*, *Fomes laricis*, and *Echinodontium tinctorium*. In most localities in the northwest *Trametes pini* often continues to fruit abundantly on dead logs and stumps long after the death of the trees, but in the southwest the dry climate usually prevents the formation of sporophores except

on living trees, and then only sparsely. This is considered the chief reason for the greater prevalence of this fungus in the northwest.

Polyporus schweinitzii fruits on the roots and dead stumps of conifers, especially of the Douglas fir, all over the forests of the western United States, but more abundantly in the northwest, and for this reason will be difficult to control, as ordinary burning of the slash in lumbered areas will not eradicate it.

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INFECTION EXPERIMENTS WITH THE POWDERY MILDEW OF WHEAT

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In a former paper (4) I have published the results of a large number of inoculation experiments with the conidial stage of the common powdery mildew, *Erysiphe graminis* DC., which occurs on the three cereals, barley, rye and wheat. The data there recorded, taken together with the results of the earlier work of Marchal (1), Salmon (5, 6, 7, 8) and myself (2, 3), which have been fully summarized in the paper referred to above, indicate clearly that biological specialization has proceeded to such an extent that a distinct form or race of the mildew is now found on the species and varieties of each of the four genera of the cereals—Avena (oats), Hordeum (barley), Secale (rye), and Triticum (wheat). All of the results published tend to establish the fact that the mildew which occurs on any one of these genera will not normally pass over on to a species belonging to any of the others. There are, therefore, distinct biological forms on each genus of the cereals.

The fact has further been established that none of these cereals can be infected by the fungus which occurs on other grasses. A large amount of data have been accumulated which indicate very clearly a marked specialization of *Erysiphe graminis* on its different hosts. So far as tested it is doubtful if conidia from a plant of one genus can infect a plant belonging to the species of any other genus.

It has further been found that, in certain cases at least, some species of a genus may be immune to the mildew which occurs on other species of the same genus. Several species of Hordeum, notably *H. bulbosum*, *H. jubatum*, *H. murinum*, *H. secalinum*, and *H. silvaticum* are almost perfectly immune to the mildew obtained from *H. vulgare*. Further, although a particular species may be a host for a given mildew, certain varieties of that species may be entirely immune to infection. A striking case of this sort is that of some of the emmers, varieties of *Triticum dicoccum*. Black Winter emmer and Red emmer are quite susceptible to infection with conidia from the common wheat, while Common emmer, Russian emmer, and White emmer are practically immune. These results with the wheat and barley mildews are quite different from those obtained with Avena where all the species tested have been found entirely susceptible to the oat mildew.

In connection with other experimental work I have carried out a large number of additional tests with certain mildews in the course of

which a large amount of data, bearing upon the problem of susceptibility and immunity of different plants, have been obtained. The results obtained with the wheat mildew on the species and varieties of Triticum are here brought together.

The seed for these experiments has been obtained from a number of different sources. I am indebted to Mr. M. A. Carleton, Bureau of Plant Industry, Professor C. E. Saunders, Central Experimental Farm, Canada, and Professor C. A. Zavitz, Guelph, Ontario, for a number of samples. From Doctor Franz Bubák, Director of the Botanical Garden, Tabor, Bohemia, I obtained a large number of different European varieties, the results from some of which have proved to be of special interest.

SUMMARY OF RESULTS

HOST	No. tests	No. plants inocul'd	No. plants infected	% of infection
Triticum compactum Host	4	16	15	93+
* " " var creticum Alef	11	35	7	20
* " " " rufiolum Kcke	5	18	16	88+
*Triticum dicoccum Schrank var africanum Kcke	10	28	23	82+
" " " " bauhnii Alef.	3	4	4	100
" " " " Black Winter emmer	6	21	19	90+
* " " " " bruneum Alef	5	13	13	100
* " " " " cladurum Alef	4	12	12	100
* " " " " Common emmer[1]	7	44	4	8+
* " " " " farrum Bayle	5	15	15	100
* " " " " fuchsii Kcke	13	37	12	32+
* " " " " macrantherum Kcke	4	11	11	100
* " " " " Red emmer[1]	6	35	35	100
* " " " " Russian emmer[1]	6	27	0	0
* " " " " Spring emmer	6	18	0	0
* " " " " White emmer[1]	21	67	3	4+
*Triticum durum Desf. var. affine Kcke	5	18	18	100
* " " " " africanum Kcke	6	20	20	100
* " " " " alexandrinum Kcke	4	13	13	100
* " " " " arnautka	4	11	11	100
" " " " (Cherson)	4	13	13	100
* " " " " fastuosum Lag.	4	7	7	100
* " " " " hordeiforme Host	3	7	7	100
* " " " " Kubanka	6	14	14	100
* " " " " obscurum Kcke	4	12	12	100
* " " " " reichenbachii Kcke	3	12	12	100
Triticum monococcum L.	4	14	10	71+
*Triticum polonicum L. var. attenatum Kcke	6	20	18	90
* " " " " compactum Krause	3	8	8	100
* " " " " velutinum	5	12	12	100
Triticum spelta L.	4	8	8	100
* " " " var. album Alef.	10	29	29	100
" " " " erubescens	4	11	11	100
" " " " Red Winter	3	5	5	100
*Triticum tumonia Schrad.	6	21	14	66+
Triticum turgidum L. var. compositum	10	25	24	96
" " " " dinura	4	18	18	100
" " " " graecum	4	12	12	100
* " " " " (Marathon)	6	19	18	94+

	HOST.	No. tests	No. plants inocul'd	No. plants infected	% of infection
*	Triticum vulgare Vill. var. albidum Alef.	9	20	20	100
*	" " " " alborubrum Kcke.	8	23	3	13+
	" " " " alborubrum Kcke.	8	21	18	85+
*	" " " " aristatum Alef.	10	31	28	90+
	" " " " aristatum Schübl.	9	29	29	100
*	" " " " aristatum Schübl.	7	25	13	52
	" " " " Australian	4	12	12	100
*	" " " " barbarosa Alef.	3	5	5	100
*	" " " " caesium Alef.	12	41	0	0
	" " " " Chul	4	11	6	54+
*	" " " " coerulea-velutinumKcke	9	28	28	100
*	" " " " Crail Fife	4	10	10	100
	" " " " Crimean	4	13	13	100
	" " " " cyanothrix Kcke	7	20	11	55
*	" " " " Defiance	6	10	10	100
	" " " " erythrospermum Kcke	7	20	20	100
*	" " " " erythrospermum Kcke	8	26	22	84+
	" " " " ferrugineum Alef.	8	21	21	100
*	" " " " ferrugineum Alef.	9	29	2	6+
	" " " " Fultz	1	5	5	100
	" " " " Fultzo-mediterranean	4	13	12	92+
	" " " " galgalos	4	7	7	100
	" " " " Gold coin	4	12	12	100
*	" " " " graecum Kcke.	15	43	43	100
*	" " " " Hayne's Blue Stem	5	11	11	100
*	" " " " leucospermum Kcke	7	21	21	100
*	" " " " milturum Alef.	8	22	22	100
	" " " " muticum Bayle	27	95	88	92+
*	" " " " muticum Bayle	12	31	27	87+
	" " " " New Zealand	4	5	5	100
	" " " " pyrothrix Alef.	8	27	25	92+
*	" " " " pyrothrix Alef.	8	16	0	0
	" " " " Red Russian	4	7	7	100
	" " " " Rieti	4	7	7	100
*	" " " " Rysting's Fife	4	8	8	100
	" " " " Theiss	6	13	13	100
	" " " " Turkey Red	21	72	72	100
*	" " " " Washington Blue Stem	6	15	15	100
	Triticum sp. indet. var. Tibetan[2]	4	13	13	100

*Indicates a spring variety; the others are winter varieties so far as known.

[1] These results taken from my previous paper.[4]

[2] This variety was received from Professor C. E. Saunders. It came originally from Thibet where it grows at high altitudes, but the form sent is of his own selection.

In carrying out these experiments the methods developed in my former work were employed. The stock cultures of the mildew were kept growing on seedlings of Turkey Red wheat. The young seedlings for inoculation were grown in small pots and inoculated with spores when the first green leaf was 1–3 cm. long. The plants had obtained this size usually about seven days after planting the seed.

After inoculation three to five pots were placed in a saucer under a large bell glass. The latter was raised above the level of the table

about two inches and thus a free circulation of air was provided. Water was placed in the saucers as the plants required it.

Controls were kept in practically all of the experiments. No infection of these was observed except in a very few cases, where, doubtless, accidental inoculation occured at the time the conidia were placed on the plants.

The experiments were allowed to continue from one to two weeks. If infection occurred at all it could be easily observed three or four days after inoculation. Within a week a susceptible plant would show large numbers of the newly formed conidia of the fungus on the inoculated parts. While a number of observations were made only the final result is recorded in the summary.

In the above table the results of tests with seventy-eight varieties are given. These varieties are distributed among nine different species of the genus Triticum. However, by far the larger number of the varieties tested belong to the one species *T. vulgare.*

In nearly all of the tests the conidia used for inoculation were obtained from the Turkey Red wheat, a variety of *T. vulgare* which is in common cultivation. In a few cases the spores were obtained from some other variety. Since, however, the latter had been inoculated with conidia from Turkey Red, it was not considered necessary to indicate the particular cases where the mildew was obtained from some variety other than Turkey Red. All of my results tend to establish the fact that the wheat mildew is the same on all of its hosts.

It is interesting to note the high percentage of infection obtained. Forty-nine of the seventy-eight varieties gave 100 per cent infection. These varieties, therefore, proved perfectly susceptible to the mildew. Fifteen of the remaining twenty-nine varieties gave an infection of 70 per cent or higher. Of the remaining fourteen varieties four were infected in 50-70 per cent of the trials, six gave only a slight infection, four gave 32 per cent and the remaining four proved to be immune. Of the immune varieties two belong to *T. dicoccum* and two to *T. vulgare.*

A study of the tabular summary shows that one or more varieties of every species is susceptible to the wheat mildew. None of the species have proved to be immune from the fungus. While Einkorn (*T. monococcum*) has proved to be harder to infect than certain varieties of the other species, yet even in this case the percentage of infection is 71.

Marchal has reported that *Triticum dicoccum* is immune to the wheat mildew. In the above list are included the results of tests with

thirteen varieties of this species. Of these varieties, six are perfectly susceptible, two are capable of a high percentage of infection, three are only slightly susceptible, and two are immune. In consequence, *T. dicoccum*, instead of being listed as an immune species is to be regarded as a host of the same mildew which occurs on the other species of the same genus. These results indicate further the necessity for testing out different varieties of those species of cultivated plants in which the development of new types has occurred.

While by far the larger number of varieties of *Triticum vulgare* are entirely susceptible to the mildew yet one can note important differences in the behavior of the various sorts. Some varieties, so far as tested, appear to be immune to the fungus even when grown right beside others abundantly infected and inoculated with conidia from the same source and treated in every way in a similar manner. The following four varieties show either entire immunity from the mildew or a high degree of resistance : *alborubrum*, *caesium*, *ferrugineum* and *pyrothrix*.

The varieties of the different species which show a marked resistance to the mildew are all spring varieties. In some cases two varieties which are very similar and even may go by the same varietal name, but differ in that one is a winter form and the other a spring, show marked differences in their behavior to the mildew. The winter variety is susceptible while the corresponding spring variety is relatively or entirely immune. The winter variety *ferrugineum*, for example, gave an infection of 100 per cent, twenty-one plants being inoculated, while the spring variety of the same name gave an infection of only 6 per cent. twenty-nine plants being inoculated. In the case of the variety *pyrothrix*, the winter variety was infected in 92 per cent of the cases (twenty-seven plants), while the spring variety was entirely immune (sixteen plants inoculated). Similar results have been obtained with varieties *alborubrum* and *aristatum*. The emmers, Common, Russian, Spring and White, which show a marked resistance to infection, are also spring varieties.

As stated above, I have found no evidence of a specialization of the wheat mildew within the genus on its various hosts. To be sure, the mildew used came from the same source, being found four years ago on some wheat plants which had been brought into the greenhouse from the University Experimental Farm.

In this connection mention is made of Steiner's interesting work on the powdery mildew of Alchemilla, *Sphaerotheca Humuli* (DC.) Burrill. Steiner (9) finds that the mildew on Alchemilla is confined to the species of this genus, thus confirming the results of Salmon. He also

claims to be able to distinguish "biological under-species" or "small biological species" within this genus of host plants. For example, conidia from *Alchemilla pastoralis* and *A. flexicaulis* are alike in infecting power except that conidia from the former will not infect *A. alpigena*, also infecting *A. pubescens* doubtfully, while conidia from *A. flexicaulis* infect *A. alpigena* doubtfully and not *A. pubescens* at all. Another case is that of the mildew on *A. impexa*, which will not infect *A. alpina vera* and *A. nitida*, while conidia from *A. pastoralis* partially infect these plants. Steiner further found that conidia from species of the Vulgares group will not produce full infection on species of the Alpinae group, although conidia from alpine species produce full infection of the species of the former group. Steiner supposes that the mildew on the alpine species came originally from Vulgares species and is only partially adapted to the new hosts. He also believes that the appearance of the mildew on alpine species is due to the influence of environment. He describes an experiment in which he grew one set of three alpine species in a warm close greenhouse and another set in the open. The former became badly mildewed from nearby Vulgares species, while the other plants remained practically free from mildew, although exposed to infected plants.

Steiner places the Alchemilla species in three groups, on the basis of their susceptibility: (1) susceptible species, as *A. impexa;* (2) immune species, as *A. conjuncta;* (3) and species susceptible to the mildew from some plants, while immune to that from other plants, as *A. micans*. Steiner also claims to have found "bridging species," for example, conidia from *A. connivens* and *A. pubescens* infected *A. pastoralis* and *A. impexa*, but not *A. micans*, while conidia from *A. pastoralis* and *A. impexa* infected *A. micans*. Thus the mildew is carried over from *A. connivens* and *A. pubescens* to *A. micans* through *A. pastoralis* and *A. impexa*. Similarly *A. impexa* is a "bridge" from *A. nitida* to *A. fallax*. In addition to the fact that only a few tests were made, Steiner does not tell us what the infecting powers of the mildew thus produced on *A. micans* and *A. fallax* are.

Steiner's results would be much more convincing, if they were based on a larger number of tests. The further fact may be noted that a large number of infections occurred on the control plants in his experiments. There were no less than fifty foreign infections in a total of three hundred and sixty-six tests.

In conclusion it may be well to call attention to the fact that the immunity which a host plant enjoys from the mildew may be due largely to the environmental conditions. I have been carrying on a large number of experiments along this line and I am convinced that

various factors, as water supply, nutrition, relative abundance of spores, etc., play an important part in the susceptibility or immunity of a particular plant to a fungous parasite.

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THE CHESTNUT BARK FUNGUS, DIAPORTHE PARASITICA.

C. L. SHEAR

Since the description, in 1906, of *Diaporthe parasitica* by Murrill[1], the writer has had under consideration the question of the generic and specific identity of this organism. That it is not a typical Diaporthe is apparently indicated by our studies of its life-history. Cultures from single ascospores of the chestnut fungus have produced typical pycnidia and pycnospores as found on the chestnut, but none of the slender, curved or hooked bodies which we have called scolecospores[2] and which seem to be a rather constant characteristic of the pycnidial forms of typical Diaporthe species, have been found. Our unpublished pure culture studies of the life histories of *Diaporthe viticola*, *D. oncostoma*, and one or two other species, have conclusively proven, for the first time so far as known, the genetic relation of the pycnidial forms referred to Diaporthe by Nitschke and others and now mostly included in the form genus Phomopsis.

The relation of *Diaporthe parasitica* to the genus Valsonectria will not be considered at this time.

Our early unpublished studies of the chestnut bark fungus, made in 1907, convinced us that it was most closely related to the genus Endothia, as that genus is at present interpreted by mycologists. This opinion was also reached by Dr. Farlow, as reported by Clinton[3] in 1908.

A more recent study and comparison of an abundance of fresh material of *Endothia radicalis* (Schw.), and *Diaporthe parasitica* Murr., in both pycnidial and ascogenous stages, and also of pure cultures of both made from ascogenous fructifications, has brought out more clearly the resemblance as well as the differences between these two species. In their pycnidial condition on their hosts and in cultures, we have been unable to find any characters to separate them. The perithecial stromata, and especially the ascospores, however, show morphological differences of specific value.

Since reaching these conclusions, we have been informed that Farlow and Clinton have both announced, in papers read before the recent

[1]Murrill, W. A. A new chestnut disease. Torreya, **6**: 186-189. 1906.

[2]Shear, C. L. The ascogenous form of the fungus causing dead-arm of the grape. Phytopathology **1**: 116. August, 1911.

[3]Clinton, G. P. Chestnut bark disease, Diaporthe parasitica Murr. Conn. Agr. Exp. Sta. Rept. **31**: 879. 1908.

conference on the chestnut bark disease, held in Harrisburg, that they regard *Diaporthe parasitica* as specifically distinct from *Endothia gyrosa* (Schw.), using this name as synonymous with *Endothia radicalis* (Schw.). It is still a question, with us at least, whether *Endothia gyrosa* is the same as *E. radicalis*. The specimen of *Sphaeria gyrosa* in Schweinitz's herbarium is too poor to determine this point conclusively. It appears evident, however, from the data at hand, that Schweinitz confused two species of fungi under this name.

It is still uncertain whether *Diaporthe parasitica* is an indigenous American fungus or not. It is also a question whether the fungus reported as *Endothia gyrosa* and *E. radicalis*, in Europe, is the same as that to which the same names are at present applied in this country, and the exact relation of this European fungus to *Diaporthe parasitica* is also somewhat doubtful. The writer is now investigating these questions and hopes to discuss them more fully later. One point at least we believe to be definitely determined and that is the specific distinction between *Diaporthe parasitica* Murr., and *Endothia radicalis* (Schw.).

U. S. DEPARTMENT OF AGRICULTURE,
WASHINGTON, D. C.

PHYTOPATHOLOGICAL NOTES

Editorial Announcement. Beginning with this number, it is proposed to establish a department of Phytopathological Notes. Under this caption will be published scientific notes *not exceeding two hundred words in length.* It is a matter of common knowledge that many results of work in plant pathology which are complete in themselves, or as complete as they are likely to be made, are often suppressed by the author for many years, if not permanently, for lack of a suitable place of publication. For example: A perusal of such recent works as Vol. 2 of Smith's "Bacteria in Relation to Plant Diseases," or Stewart's "Notes on New York Plant Diseases," Geneva Station Bulletin 328, shows that many isolated, but perfectly rounded, observations have been held unpublished for ten or fifteen years. It is the object of this department to furnish a place for the fairly prompt publication of such notes.

Items of news of especial interest to plant pathologists will also be published. Facts regarding changes of positions in plant pathology, legislation affecting plant pathology, notes involving economic bearings, and questions of application of plant pathology will be considered legitimate subject matter. No items of merely personal interest will, however, be considered.

Dr. Metcalf has consented to take charge of this department, and manuscript intended for it may be sent directly to Dr. Haven Metcalf, 1223 Vermont Avenue, Washington, D. C.

Root and Culm Infections of Wheat by Soil Fungi in North Dakota.

Since the publication of my article under this title in the December number of Phytopathology, my attention has been directed to an article which should have been cited in that paper. The article to which I refer is a paper by Doctor Erwin F. Smith of the Department of Agriculture, Washington, D. C., entitled, "The Fungous Infestation of Agricultural Soils in the United States," read August 25, 1899, at Ohio State University, Columbus, Ohio, before the Botanical Section of the American Association for the Advancement of Science. This article may be found in the Scientific American Supplement, No. 1246, for November 18, 1899, page 19981. By this article it will be seen that credit for the belief that soil may become "sick" with pathogenic fungi is due to Doctor Smith rather than to later authors.

T. D. BECKWITH

A congress, summoned by Governor Tener of Pennsylvania, to consider ways and means of controlling the chestnut bark disease, was held at Harrisburg, Pa., on February 20-21. Representatives were invited from all the chestnut producing States and fifteen of them besides Canada were represented by one or more persons. This congress was probably the most important one that has ever been called together to consider a fungous disease and indicates a new attitude on the part of the public toward plant pathology. Considerable difference of opinion was shown as to the advisability of making any effort to control the disease. The most conspicuous fact brought out by the congress was the small amount of scientific research which has been done on this disease, and the great conservatism that has hitherto prevailed regarding its extent and contagious nature. The resolutions adopted cannot be given in full but the salient features are: commendation of the Pennsylvania Chestnut Tree Blight Commission, which has charge of the problem in that State, favoring prompt action by the states in attempting to stamp out the disease beyond certain boundaries, favoring the Moore bill now before Congress appropriating $80,000 for work on this disease, and commending the Simmons plant disease quarantine bill now before Congress. The proceedings of the congress are to be published and distributed.

Recent changes of position of phytopathologists are as follows: Dr. F. L. Stevens has left the North Carolina College of Agriculture, West Raleigh, N. C., to become Professor of Plant Pathology and Dean of the Agricultural College of Porto Rico and Director of the Tropical Botanical-Zoölogical Laboratory, Mayagüez, Porto Rico. Dr. Stevens is succeeded by H. R. Fulton, hitherto of the Pennsylvania State College. Dr. M. T. Cook has left the Delaware Experiment Station to become State Pathologist of New Jersey, at New Brunswick, N. J., and is succeeded by T. F. Manns, of the Ohio Experiment Station. W. M. Scott has left the Bureau of Plant Industry, to assume the directorship of a department of research on fungicides and insecticides with the Thomson Chemical Co., Baltimore, Md. New appointments are: Dr. F. H. Blodgett, to the Texas Experiment Station, College Station, Texas; F. D. Bailey and H. L. Rees, to the Oregon Experiment Station, Corvallis, Ore.; Dr. H. W. Wollenweber, recently assistant in the Kaiserliche-Biologische Anstalt at Dahlem-bei-Berlin, is now with the Bureau of Plant Industry, where he is engaged in the preparation of an extensive monograph of the genus Fusarium.

WASHINGTON MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY (Concluded).

Large Leaf-Spot of Chestnut and Oak. ARTHUR H. GRAVES

This disease, attacking leaves of *Castanea dentata* and *Quercus rubra*, was observed by the writer in the summer of 1910 to be common in the southern Appalachian region.

It appears about the beginning of August as small, brownish, circular spots, ½-2 cm. in diameter. As the disease progresses, concentric bands of diseased tissue are added to the original circular area until the final spots often reach 5-6 cm. in diameter. Several large spots occurring in a single leaf may join each other, and often, in this way, over half of the leaf may be killed.

The disease is caused by *Monochaetia desmazierii* Sacc., one of the Fungi Imperfecti. Cultures of the fungus have been made in various media, in all of which the mycelium grew vigorously, and in many of them spores were produced.

In some cases, individual trees were observed to have lost perhaps 40% of their green assimilating tissue as a result of the attacks of this fungus. Usually, however, the damage is much less than this, but always sufficient, it is believed, to cause a considerable diminution in the annual wood increment.

Parasitism of Phoradendron juniperinum libocedri. E. P MEINECKE

Phoradendron juniperinum libocedri on *Libocedrus decurrens* is best known as a small hanging shrub formed by a bunch of rather thin, slender and brittle leafless stems.' It causes a not very conspicuous swelling of the branch it inhabits. Like other Phoradendra and *Viscum album*, it is light-seeking, and therefore preferably grows high up in the crown of the tree. It grows, however, with and in its host to an old age, causing swellings of considerable size. These swellings show few, very small, or no green sprouts at all; in the bark and the living sapwood the mistletoe is vigorously growing. Dead sinkers in great numbers are found in the heartwood. In one case it was found that the mistletoe had inhabited the trunk for at least 219 years.

The fact that the plant is capable of living for a great number of years without developing any green exterior parts indicates that *Phoradendron juniperinum libocedri*, at least from a certain age on, relies on its host not only for its inorganic, but also for all organic food supply. In other words, becomes a true parasite.

Control of the Blackleg Disease of the Potato. W. J. MORSE

Blackleg or black stem-rot, a bacterial disease of the stem and tuber of the Irish potato, has recently become of considerable economic importance in certain potato growing sections where seed tubers are largely produced for seed for southern planting. Studies and experiments made in Maine during the last few years indicate that under the climatic conditions which there exist the germs of the disease do not remain alive in the soil over winter and the source of infection is probably entirely from diseased seed tubers.

Rigid selection of perfect seed tubers for planting, and disinfecting, by means of formaldehyde, as for potato scab, have both been found to be effective control measures. Cooperative experiments involving about 300 acres of potatoes on eight different farms in 1911 indicate that it is possible entirely to eliminate the disease

from a given farm or section in from one to two year's time by combined selection of seed tubers and formaldehyde disinfection. In the hands of the average farmer formaldehyde solution is more effective than formaldehyde gas.

The Effect of Heavy Inoculation with Conidia of the Wheat Mildew upon Mildew-Resistant Emmers. GEORGE M. REED Read by title.

An Edible Smut. FLORA W. PATTERSON

This paper, illustrated with photographs and fresh specimens of *Ustilago esculenta* P. Henn, called attention to a rare and interesting fungus collected probably for the first time in America. It developed upon *Zizania latifolia* in one of the greenhouses of the U. S. Department of Agriculture.

The Toxicity of Plant Acids and Enzymes. MEL T. COOK AND J. J. TAUBENHAUS Read by title.

The Potato Fusarium Situation in Europe and America. W. A. ORTON No abstract.

Notes upon Tree Diseases in the Eastern States. PERLEY SPAULDING

The chestnut blight in 1909 was relatively rare in the Connecticut valley between New Haven and Hartford. In 1911 it was so common as to be visible from the car window practically all the time. In Maryland it has been found that the northeastern corner, included by a straight line running from Baltimore eastward and a curved line running westward, then northward, is so badly diseased that there is little hope of controlling it. It has been at Parkton for six years and probably seven or eight.

A serious needle disease of balsam fir is caused by *Lophodermium nervisequum* (DC) Fr. in the Adirondack region. It causes the death of much young growth. Infection occurs in June on new needles and fruiting bodies are formed on the same needles about a year later.

Spores of *Peridermium fructigenum* Arthur were sown on leaves of ten American species of Rhododendron and Kalmia without any resulting infection.

Lightning is much more serious in Maryland as a tree destroying factor than is commonly supposed. An average of three or four chestnut trees per square mile were killed or crippled the past summer.

An apparently serious disease of species of maple is caused by *Myxosporium acerinum* Peck. This disease is widespread and affects the smaller branches. Cutting out and burning the affected branches seems to be the only practical method of treatment.

Phoma piceina Peck, causes a very serious disease of Norway and other spruces. It causes defoliation and consequent death of large trees.

Notes on Diseases of Trees in our National Forests. II. GEORGE GRANT HEDGCOCK

A brief mention was made of a number of the principal wood-rotting fungi which cause disease in living trees in national and other forests in the United States. A list of the host trees attacked by each was given, which included many hosts hitherto unreported.

Diseases of Coniferous Stock in Western Nurseries. CARL HARTLEY Read by title.

Notes on Some Heteroecious Rusts of Connecticut. G. P. CLINTON

In continuation of the article published in the Botanist's Report of the Connecticut Agricultural Station for 1907, pp. 369-396, the following additional items are given:

The telial stage of *Gymnosporangium japonicum* Syd. is reported for the first time in America, having been collected by the Station's entomological inspectors in the spring of 1911 on two different importations of *Juniperus chinensis* from Japan.

Peridermium peckii Thm. is shown by artificial inoculations to be the aecial stage of *Pucciniastrum myrtilli* (Schum.) Arth.

Pinus austriaca, *P. maritima* and *P. ponderosa* are reported as new American hosts for *Peridermium pyriforme* Pk.

The following are noted as species or stages not reported from Connecticut in our previous article:—*Calyptospora columnaris* (A. & S.) Kuehn (its III stage only); *Cronartium ribicola* Waldh. (its I stage, *Peridermium strobi* Kleb. on *Pinus strobus*); *Pucciniastrum arcticum* var. *americanum* Farl. (its II stage only); *Pucciniastrum myrtilli* (Schum.) Arth. (its II stage); *Cronartium quercus* (Brond.) Schroet. (its I stage, *Peridermium cerebrum* Pk. only, but its III stage was produced artificially on oaks); *Melampsora bigelowii* Thuem. (its Caeoma stage on *Larix*).

Some Notes on Sphaeropsis malorum. CHARLES BROOKS and MARGARET DEMERITT

Two forms of Sphaeropsis have been isolated from decaying apples. One produces spores typical of *Sphaeropsis malorum*, the other, spores that are longer and that are oblong rather than oval in outline. The pycnidia of both forms are ostiolate but those of the latter are papillate while those of the former are not. The two forms retain their distinctive characteristics when grown on the same culture medium. Both forms have been obtained from the fruit but the long spored one much more often. The pycnidia from cankers have nearly always contained the long spores. Only the long spored form has been obtained from the foliage. In inoculations on foliage, positive results have been obtained only with the long spored form. The large number of leaf spots beneath cankers have furnished good evidence of the transfer of the fungus from the limb to the leaves.

Winter Killing and Smelter Injury in the Forests of Montana. GEORGE GRANT HEDGCOCK

A comparison was made of the visible effects on coniferous forest trees caused by winter killing, and those produced by the fumes of the great Washoe smelter at Anaconda, Montana.

Sexual Fusions in Uredo lini. F. D. FROMME No abstract

Apple Scab Infection as Correlated with Maturity of Ascospores, Weather Conditions, and Development of Fruit Buds. ERRETT WALLACE

From observations covering a period of three years in New York State, it is concluded that: The primary spring infection usually occurs about the time the ascospores mature, if weather conditions at that time are favorable. The ascospores usually mature about as the apple blossoms are ready to open. There seems little danger of serious infection earlier than this whatever the weather conditions may be.

Later secondary infections were closely followed and the probable date of each infection and the particular rain during which it occured was located. It was possible to do this by means of three types of observations. First, determining the incubation period by means of artificial inoculation ; second, by watching closely for each new appearance ; third, by keeping a careful weather record and tracing back from each new appearance to the infection weather occuring nearest the probable time of infection as indicated by the previously determined incubation period.

The Development of Gloeosporium malicorticis Cordley. H. S. JACKSON

This paper deals with the study of what is shown to be the "perfect" or ascospore stage of *Gloeosporium malicorticis*. The author has had this stage under observation for three years and the fungus is found to belong to the Mollisiaceae. The apothecia are found constantly associated with the old acervuli of the conidal stage and appear in the dead bark of old cankers one year after the maturity of the conidial stage. The writer has never failed to find this stage in any orchard in which he has searched.

The spores germinate readily in water or nutrient agar. Pure cultures from ascospores and from spores germinating within the ascus were obtained and inoculations made. It takes one year for the cankers to mature. All inoculations produced typical cankers, which bore the typical conidia of *Gloeosporium malicorticis*. No cankers appeared at any of the check punctures. The typical conidia have not as yet been developed in pure culture, since only the secondary spores develop under artificial conditions.

The resemblance in both conidial and ascospore stages to *Pseudopeziza ribis* was pointed out. The exact generic position is somewhat doubtful. The fungus, however, was described as **Neofabrea malicorticis** (Cordley) N. Comb.

Some Wood Preservatives, with Special Reference to Their Toxic Properties. C. J. HUMPHREY. No abstract.

Silver Leaf, a Disease of Fruit Trees. H. T. GÜSSOW No abstract

Fruit Spot of Apple and Quince. CHARLES BROOKS and CAROLINE A. BLACK
Published in full in this issue.

The Detection of inert Ingredients of Fungicides. ERRETT WALLACE and L. H. EVANS

The paper consists of a brief report on some work carried out for the Insecticide and Fungicide Board along the line of the above suggested topic.

The method described in Cornell Bulletin No. 290, by one of the writers and his associates, was used.

The following substances were tested with reference to their action on conidia of *Glomerella rufomaculans* and *Sclerotinia fructigena*, and certain conclusions were drawn with reference to each of the following substances :

Calcium oxide, calcium carbonate, calcium sulphate, calcium sulphite, magnesium oxide, lead oxide, lead arsenate, and zinc oxide.

Interesting results were also obtained from experiments with lime-sulphur solutions showing their behavior towards spores of the brown-rot organism.

The Trend of Investigation in Plant Pathology. H. A. HARDING
Read by title.

A Serious Root Disease of Radish. J. T. BARRETT

This paper deals with a disease of radishes characterized by a peculiar browning or blackening of a portion or all of the root, and although observed for a number of years and widely distributed over the country, the cause has until recently remained unknown. Deformities due to retardation of growth are common.

The infected tissue in the early stages of the disease remains sound and brittle and has no unpleasant taste or odor. As the disease progresses the cells are more or less broken down and rots due to saprophytic forms frequently set in. The disease in Illinois is a very serious one in many localities where not infrequently a large part, if not the entire crop, is rendered unmarketable. Seedlings under certain conditions are also infected and sooner or later die. The stems become shrunken at the surface of the ground and the plants finally fall over.

The organism which is the cause of this disease is *Aphanomyces levis* de Bary, one of the Saprolegniaceae and long known as a saprophyte inhabiting the soil and water. The mycelium in the tissue of the radish is very delicate and evanescent in character and easily overlooked. It is intercellular and partially dissolves the middle lamella of the cells.

Infection in the soil is due, no doubt, to the numerous swarm spores which are produced in large numbers, especially in wet situations. Oospores are easily produced and very probably carry the fungus over winter. No successful means of control has as yet been found.

The Method of Spreading of the Olive Knot Disease. WM. T. HORNE, WM. B. PARKER and LYMAN L. DAINES

This article is a brief progress report on studies carried out at Fairoaks near Sacramento, California, to discover a method for controlling the above disease which at one time caused considerable concern in that section. Dr. Erwin F. Smith's work on the causative organism, *Bacterium savastanoi* E. F. Smith, (Bul. 131, Part IV, Bur. Pl. Ind., U. S. Dept. Agric., 1908), was taken as the starting point. No biting or piercing insect or other transporting agent was discovered, but it was found that vigorous knots exude bacterial slime when wet. It was demonstrated, both by platings from the slime and from direct inoculations, that this slime contains the specific organism in abundance. Dissemination of the bacteria seems to be adequately accounted for by the spattering of rain, and by accidental tracking of birds and insects and by various other agencies. Entrance into the living bark seems usually to take place on healed wounds and is evidently accomplished in nature by the washing down of the organisms into natural fissures in the bark where they are protected and kept moist until they can grow and make their way through into the living tissue. Inoculation on the uninjured bark of a non-infected tree has been accomplished by wetting with an infusion of the organism, but these results have not yet been confirmed repeatedly, and the details of the demonstration are reserved for the fuller discussion which is promised as soon as remedial measures are most fully worked out.

Preliminary Notes on a Twig Blight of Quercus prinus. DELLA INGRAM

Mentions an apparently serious disease of the chestnut oak (*Quercus prinus*) noticed by members of the Office of Forest Pathology for the first time in the spring and summer of 1911. The range of the disease has not yet been determined, but it has been reported from Connecticut and from various points in Virginia, Maryland and Pennsylvania.

Viewed at a distance, the diseased trees have somewhat the appearance of having been attacked by "fire-blight," the tips of the branches and leaves, having the brown, blighted appearance characteristic of that disease. Trees of all ages and sizes may be attacked, but those under about eight feet in height seem to be the most susceptible. The young growing tips and smaller branches are attacked most readily, but occasionally branches as large as one-half inch in diameter are found affected. All leaves, regardless of size, on the diseased branches, wither and dry up. Cross sections of the infected twigs show a perceptible darkening of the cambium, and, in the later stages, of the wood and bark also.

A definite fungus is found associated with the disease and is undoubtedly the cause of the trouble. The life-history has not been followed for a long enough time to admit of a definite taxonomic position. The stage most prevalent in the field agrees with *Dothiorella quercina* (C. & Ell.) described as saprophytic on dead wood of yellow oak from New Jersey in 1895. As the fruiting bodies appear in abundance on the dead twigs, it is quite possible that only this stage was observed. Further work is in progress, the results of which will be published later.

The Relationship of Oospora scabies to the Higher Bacteria. G. C. CUNNINGHAM

Three strains of a filamentous, branching, irregularly segmented organism have been isolated from potato scab and found to produce the disease when reinoculated into growing potatoes. A study of these organism shows them to be closely related to, if not identical with, the organism described by Dr. R. Thaxter (1890) as *Oospora scabies*. The genus Oospora formed by Wallroth (1833), and as recognized by Saccardo has little permanent scientific value. It is a poorly defined genus and has received many organisms which have been later transferred to other genera.

Thaxter suspected the bacterial nature of the organism, but at the time when he wrote his description little was known regarding the nature of the higher bacteria. The two characters, true branching and aerial fruiting, which he considered sufficient to separate it from the bacteria are now recognized as important characters of the family Mycobacteriaceae and of the genus Streptothrix. It is evident from our study and from the work of Dr. Thaxter that the characters observed, when viewed in the light of our present knowledge of the higher bacteria, are sufficient to place this organism in the genus Streptothrix.

Further Notes on the Chestnut Bark Disease. HAVEN METCALF Read by title.

Some Observations on Experiments with the Chestnut Bark Disease. J. FRANKLIN COLLINS

Observations on experiments that were undertaken in 1907 to determine if individual chestnut trees could be saved after they had once become infected with the Chestnut Bark Disease. The three main points of the paper are; (1) that the mycelium, contrary to common belief, can penetrate and continue to grow in the wood under an old diseased spot after the infected bark has been removed and the surface of the wood treated with tar, paint, etc., and that fruiting pustules may, at times be produced in abundance on bare wood; (2) that "summer spores" are not as liable to be blown about by the wind as has been stated by some of the earlier observers; (3) that threads of "summer spores" are dependent mainly, if not wholly, upon certain conditions of moisture for their development—conditions which, though commonly more prevalent during the spring, may occur at any season of the year.

Ustilagineae on Andropogon sorghum (L.) in America. ALDEN A. POTTER

The smuts of sorghum, having taken on economic importance in the Great Plains area, are being investigated in the Federal Department work on cereal diseases. The "head" smut, *Sphacelotheca reiliana* (Kühn) Clinton, is still obscure in its life history. Peculiar floral alterations have been shown to be caused by it and to contain the mycelium. The sorus, when young, is edible and might be produced commercially since the sorghum plant will grow more than one crop if cut back before maturity and the infection is typically persistent in all parts of the meristem. The course of the primary infection is not known, however.

Of the kernel smuts there are two which are fully as distinct as the two smuts on oats. This has been shown by infection experiments on five varieties of sorghum. Their life history, and therefore their prevention, is similar, as in the oat smuts, and the spore forms are also very much alike. One, *Sphacelotheca sorghi* (Lk.) Clinton, has been widely studied in this country, but the other, which is Kühn's *Ustilago cruenta*, has not been recognized in American literature. It is distinct on account of the very thin, fragile membrane which usually shatters on emerging from the sheath; in the longer, curved columellae, and in frequently forming pustules on the glumes, pedicels, and panicle branches. Using Clinton's system of classification its nomenclature depends on the fungal character of the membrane in Sphacelotheca. This is in some doubt, but its other characters make it seem probable that it should take its place in American literature as *Sphacelotheca cruenta*.

Use of the Autochrome Plate Method in Plant Pathology. SAMUEL M. BAIN

The autochrome plate is especially useful for diagnostic purposes either in the illustration of original papers or for educational use. The method is comparatively simple, and may be used with either high- or low-power magnification.

The Relation of Certain Parasitic Fungi to the Age and Development of the Host Plant. MEL. T. COOK and J. J. TAUBENHAUS

Numerous experiments have proven that when laboratory inoculations are made on picked fruits or detached portions of plants, the results obtained are not sufficiently reliable. It was found that there is a difference in resistance between picked fruits kept in the laboratory, and unpicked fruits; between young and older fruits of the same tree; and between fruits of different varieties. The resistance is intimately associated with the cell contents of the host. It is believed that the *Glomerella rufomaculans* of the apple is able to attack many different hosts and this explains the presence of so many of the so-called "new species."

Flower Infection with Cotton Boll Rots. C. W. EDGERTON

Two organisms causing boll rots, will infect the cotton boll, following inoculation in the open flower, these being *Bacterium malvacearum* and *Glomerella gossypii*. The bacteria develop on the dying flower parts and finally come in contact with the young boll and there develop the characteristic spots. In the experiments conducted, 12–14 days after the flowers were inoculated, 45% of the young bolls had spots, while there were none on any of the checks. The cotton anthracnose may cause an infection in a similar way to the bacteria, or the mycelium may grow down the pistil. About 40% of the bolls become affected, following flower inoculation with this fungus. During the first three weeks, the largest percentage of infection is through the pistil; in one experiment with 28% of the bolls showing the disease in this time, 18% were infected through the pistil, 3% were infected on the lines of dehiscence, and 7% between the lines of dehiscence.

The Use of Fungicides to Prevent Damping-Off. CARL HARTLEY

During the past three summers experiments have been conducted to prevent the serious damping-off of pine seedlings in a nursery in western Nebraska. The soil is a fine sand containing some humus. Most of the disease is caused by *Pythium debaryanum*, although Fusarium and Rhizoctonia cause some damage.

Fungicides applied after germination are dangerous to the seedlings. Heating the soil to kill the parasites, and sterilizing the soil with acids or fungicidal salts which are later neutralized by adding lime, are a failure, because reinfection often takes place at once, and the parasites work much faster in sterilized than unsterilized soil. This together with inoculation experiments, emphasizes the importance of competing microörganisms in limiting the work of Pythium in untreated soil.

Sulfuric acid, because it leaves a slight residue in the soil to prevent reinfection, and also because it is very cheap and convenient, has been found the best fungicide. It is applied in aqueous solution at the time of seed-sowing. $\frac{3}{16}$ fluid ounce is used per square foot of seed-bed. Injury to seedlings is prevented by light watering twice daily till germination is complete. In ten different tests an average stand has been obtained more than 4½ times as good on the treated plots as on the controls.

The Chestnut Tree Canker Disease. W. H. RANKIN

Specimens of the mature perithecial stage of the fungus were found dehiscing spores under moist conditions throughout the summer. Plate cultures were made by allowing the asci to snap the spores onto the media. Artificial infections were produced in great number by inoculation with the mycelium from these pure cultures. A conidial stage of the fungus, differing from the usual pycnidia was found commonly developing on the wood. The sap-wood is markedly affected and the leaves killed through a toxic effect. There is evidence that the relative water and air content of the tree determines to a degree its susceptibility to the fungus.

The Chestnut Bark Disease in Massachusetts. ARTHUR H. GRAVES

In general, the regions of the state most badly infected are the Connecticut Valley and the Berkshire areas. As one proceeds eastward in the state, the infection becomes less and less marked. In general, also, the southern and western portions are infected to a much greater extent than the northern and eastern.

In all probability the years 1905 or 1906 were the first in which this disease was carried into Massachusetts. The earliest infections are often very widely remote from each other, a fact which agrees with the theory that birds rather than the wind are the carriers of advance infections. The earliest infections are also more abundant in the southern and western portions of the state, which indicates their importation from New York State and Connecticut.

It is believed that it would be practicable for the state to adopt control measures in the northern and eastern parts.

Coppice was not found more susceptible than seedlings, but burned areas are more apt to be infected than those untouched by fire.

The best time for locating chestnut bark disease is during the month of August.

There is danger of confusing the symptoms of the chestnut bark disease with those caused by other agents, such as borers, girdling rodents, etc.

Urophlyctis alfalfae, A Fungous Disease of Alfalfa, Occurring in Oregon; First Account of Its Occurrence in the State. P. J. O'GARA No abstract.

Summer and Fall Observations on the Growth of the Chestnut Bark Disease in Pennsylvania. CAROLINE RUMBOLD

The observations were made on specimens sent to the Pennsylvania Chestnut Blight Commission laboratory from different parts of the state by scouts. The observations extend from July to the present time during which the fungus has passed from the summer to the winter period in its life-history.

During the summer period the rate of growth of mycelium and production of spores is effected principally by moisture. This period lasted until the latter part of December.

During the transition period the pustules darkened in color. Often they fell off. The mycelium disappeared. The pycnidia became sterile.

Specimens gathered on the first of December in different parts of the state showed perithecia with ascospores.

[PHYTOPATHOLOGY, for February, 1912 (**2** : 1-48, *pls.* I-III) was issued February 23, 1912.]